THE UNIVERSITY OF ALBERTA

THE GEOLOGY OF THE UPPER DEVONIAN SASKATCHEWAN GROUP AND EQUIVALENT ROCKS IN WESTERN SASKATCHEWAN AND ADJACENT AREAS

BY

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A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "The Geology of the Upper Devonian Saskatchewan Group and Equivalent Rocks in Western Saskatchewan and Adjacent Areas", submitted by Donald Martin Joseph Kent, B.Sc., M.Sc., in partial fulfilment of the degree of Doctor of Philosophy.

ABSTRACT

The Upper Devonian Saskatchewan Group of western Saskatchewan consists of two major stratigraphic units, the Duperow and Birdbear Formations. Each formation has been subdivided into members containing gross lithologic characteristics which make them distinctive from each other. The Duperow Formation consists of the Saskatoon, Elstow, Wymark and Seward Members and the Birdbear Formation contains a lower and an upper member. Lithologically the Elstow and Seward Members of the Duperow Formation and the lower member of the Birdbear Formation are similar and contain fine-clastic and argillaceous carbonate rocks. On the other hand the Saskatoon and Wymark Members of the Duperow Formation and the upper member of the Birdbear Formation are predominantly non-argillaceous carbonate. Besides the non-argillaceous carbonate material the Wymark Member contains large amounts of evaporitic strata.

Macrofossils that can be used to determine regional time relationships are sparse in the strata of the Saskatchewan Group, but the combination of macrofossils, microfossils (sporomorphs) and para-time marker beds suggest that this group is a time stratigraphic equivalent of the Fairholme Group of eastern Alberta, the Woodbend Group of central Alberta and the Jefferson Group of north-central Montana. Thus, there is a facies relationship within the study area between these groups and the facies changes may be delineated by arbitrary cut-off lines which represent the line along which the major lithologic characteristics of one group are no longer easily recognized.

The carbonate rocks of the Saskatchewan Group and its lateral equivalents are dominated by three microfacies: organic (biological constructed and skeletal sands), non-skeletal sand and microcrystalline

carbonate ooze. The latter is the most common and also constitutes the matrix of the skeletal sands of the organic facies. Petrologically and geochemically many of the anhydritic deposits of the Duperow Formation are similar to supratidal evaporite deposits, but local restricted basin evaporites do occur also. The lithologies of the Saskatchewan Group and its equivalents may be interpreted as representing sediments that were deposited in a shallow shelf environment somewhat protected from excessive wave action. The shelf probably underwent several stages of subsidence and stillstand. The former is represented by the carbonate and fine-clastic lithologies and the latter by the supratidal anhydrites and to some extent by the restricted basin anhydrites.

Two regional unconformities, one within the Saskatchewan Group and the other at or near the top of the group and its equivalents represent important periods of uplift during Late Devonian time. The youngest of these erosional stages marks the close of Frasnian sedimentation in the region of study and had the effect of producing a thick weathered residue at the top of the carbonate strata of the Birdbear Formation in western Saskatchewan. During the time that the uppermost beds of the Birdbear Formation were being weathered, evaporitic deposits (represented by the evaporites of the Crowfoot and Nisku Formations) were being laid down in central Alberta. However, this region eventually came under the influence of the regional uplift and also underwent weathering and erosion.

Devonian and younger tectonic fluctuations have produced mountain building and epeirogenic movements within the study area. Some of the epeirogenic movements produced focal points where removal by solution of Middle and younger Devonian halite deposits could occur. Early re-

moval of halite from these focal points produced locally thick accumulations of the sediments which constitute the Saskatchewan Group.

The information obtained from an analysis of the regional geology of the Saskatchewan Group and its lateral equivalents suggests that the Birdbear Formation is in some respects similar lithologically to the Nisku Formation of central Alberta, but is somewhat older, and continued use of the name "Nisku" for the interval now described as Birdbear is not recommended.

Two new names for stratigraphic units are introduced - the Saskatoon Member (nov.) is the lowest carbonate member of the Duperow Formation in the western Saskatchewan area; the Elstow Member (nov.) is an argillaceous member of the Duperow Formation overlying the Saskatoon Member in the same general area.

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TABLE OF CONTENTS

		Page
ABSTRACT	-	iii
ACKNOWLEDGEMENTS	-	vi
TABLE OF CONTENTS	-	vii
LIST OF ILLUSTRATIONS	-	xii
INTRODUCTION	-	1
General Statement	-	1
Objectives of this Study	-	2
Methods and Procedures	-	2
Area of Study	-	3
Geological Setting	-	4
STRATIGRAPHY	-	6
Origin of Stratigraphic Nomenclature	-	6
Outcrop Nomenclature	-	6
Subsurface Nomenclature	-	9
General Stratigraphy	-	12
Underlying Beds	-	12
Souris River Formation	-	13
Saskatchewan Group	-	16
Overlying Beds	-	18
Three Forks Group	-	18
Detailed Stratigraphy	-	20
Duperow Formation	-	20
Saskatoon Member	-	20
Elstow Member	-	27
Wymark Member	-	30

Seward Member	-	37
Birdbear Formation	-	45
Lower Member	-	46
Upper Member	-	51
Three Forks Group	-	55
Torquay Formation - Units 1 and 2	-	55
PALAEONTOLOGY, CORRELATION AND AGE	-	57
General Character of the Fauna	-	57
Stratigraphic Distribution of the Fauna	-	57
Duperow Formation	-	57
Elstow and Saskatoon Members	-	57
Wymark Member	-	61
Seward Member	-	63
Birdbear Formation	-	65
Sporomorphs	-	66
History of the Generic Nomenclature of *Tasmanites* and *Leiosphaeridia*	-	66
Generic Characteristics	-	68
Origin	-	70
Stratigraphic Distribution	-	71
Sporomorphs in the Saskatchewan Group	-	72
Correlation	-	75
Duperow Formation	-	76
Birdbear Formation	-	79
Age	-	81
SEDIMENTATION	-	83
Sedimentary Features	-	83

Laminated Strata - 83

Disturbed Bedding - 85

Contorted Bedding - 86

Sedimentary Boudinage - 87

Indistinct Stratification - 88

Pebble Beds and Intraformational Breccias - 89

Solution Phenomena - 91

Diagenetic and Post-Diagenetic Alterations in the Carbonate Rocks - 95

Recrystallization - 96

Grain Enlargement - 96

Degrading Recrystallization - 98

Fibrous Calcite Formation - 98

Natural Mold Formation - 100

Dolomitization - 100

Distribution of Dolomite in the Saskatchewan Group - 103

Other Mineralization - 106

Secondary Silica - 106

Secondary Anhydrite - 112

Pyrite - 114

Petrology and Geochemistry of the Anhydrites - 115

Petrology of the Anhydrites - 116

Classification and Terminology - 116

Association among Varieties of Anhydrite - 118

Association of Microscopic Grain Types - 119

Interpretation of Petrological and Geochemical

Observations - 121

Sedimentary Framework - 126

Regional Facies - 127

Microfacies - 129

Organic Facies - 129

Non-skeletal Sand Facies - 130

Microcrystalline Carbonate Ooze Facies - 131

Fine-Clastic Deposits and Evaporites - 132

Distribution of Microfacies - 132

Saskatoon Member - 132

Wymark Member - 133

Birdbear Formation - 134

Other Units - 134

Tectonic Framework - 134

Depositional Environments - 137

GEOLOGICAL HISTORY - 140

SUMMARY AND CONCLUSIONS - 144

SELECTED BIBLIOGRAPHY - 146

APPENDIX A - Control Points and Formation Tops - 176

APPENDIX B - Geochemical Analyses - 222

Analytical Methods - 223

Preparation of External Standards - 224

Calculations - 226

Results - 227

APPENDIX C - Analyses of Variance - 250

APPENDIX D - Relative Ages of Salt Solution Structures 260

APPENDIX E - Selected Core Descriptions - 264

APPENDIX F - Photographs of Polished and Thin Sections 328

LIST OF ILLUSTRATIONS

Figure 1 - Index Map - after page xv

Figure 2 - Subcrop Map - - (in pocket)

Figure 3 - East-West Stratigraphic Cross Section (A-A') from the Union Grant No. 8-16 well (Lsd. 8-16-43-13W4) to the Tidewater Parkbeg Crown No. 1 well (Lsd. 10-32-18-3W3). - (in pocket)

Figure 4 - East-West Stratigraphic Cross Section (B-B') from the Imperial Canadian Superior Lee 8-28-35-17 well (Lsd. 8-28-35-17W4) to the Amerada Shell Crown "S-E" 10-26 well (Lsd. 10-26-1-13W3) - (in pocket)

Figure 5 - East-West Stratigraphic Cross Section (C-C') from the Imperial Calstan Lake Newell 5-1-17-14 well (Lsd. 5-1-17-14W4) to the Texas No. 1 Government well (C-SE-SE-11-34N-31E) - (in pocket)

Figure 6 - East-West Stratigraphic Cross Section (D-D') from the British American Pyrcz No. 1 well (Lsd. 12-25-50-26W4) to the Mobil Producing Company No. 1 Birdbear well (C-SE-NW-32-149N-91W) - - (in pocket)

Figure 7 - North-South Stratigraphic Cross Section (E-E') from the United States Borax and Chemical Elstow 5-22A well (5-22-34-1W3) to the Tidewater Parkbeg Crown No. 1 well -

(Lsd. 10-32-18-3W3) - (in pocket)

Figure 8 - East-West Stratigraphic Cross Section (F-F') from the Calstan Fort Pitt 1-25 well (Lsd. 1-25-54-26W3) to the United States Borax and Chemical Elstow 5-22A well (5-22-34-1W3) - (in pocket)

Figure 9 - East-West Stratigraphic Cross Section (G-G') from the British American Arndt 15-15 well (Lsd. 15-15-14-27W3) to the Tidewater Parkbeg Crown No. 1 well (Lsd. 10-32-18-3W3) - (in pocket)

Figure 10 - Type Section of the Saskatoon and Elstow Members of the Duperow Formation. - after page 19

Figure 11 - Isopach Map of the Saskatoon and Elstow Members. - (in pocket)

Figure 12 - Panel Diagram of the Saskatoon, Elstow and Wymark Members. - (in pocket)

Figure 13 - Isopach Map of the Wymark Member - (in pocket)

Figure 14 - Isopach Map of the Seward Member - (in pocket)

Figure 15 - Panel Diagram of the Seward Member of the Duperow Formation and the Birdbear Formation - (in pocket)

Figure 16 - Schematic East-West Cross Section of the Birdbear Formation and equivalent Strata from the British American Cities Service

	Hackett No. 1 well (Lsd. 13-15-36-18W4) to the Murphy No. 1 Firemoon well (C-SE-SE-12-30N-41E).	-	(in pocket)
Figure 17 -	Isopach Map of Lower Member of the Birdbear Formation.	-	(in pocket)
Figure 18 -	Isopach Map of Upper Member of the Birdbear Formation.	-	(in pocket)
Figure 19 -	Isopach Map of the Dinsmore Evaporite	-	(in pocket)
Figure 20 -	Schematic Cross Section Through Wells used in Geochemical Study of the Anhydrites of the Duperow Formation.	-	(in pocket)
Figure 21 -	Geochemical Profile of Anhydrites in Lower and Middle Units of Wymark Member - Duperow Formation.	-	(in pocket)
Figure 22 -	Geochemical Profile of Anhydrite in Middle Unit of Wymark Member - Duperow Formation.	-	(in pocket)
Figure 23 -	Geochemical Profile of Anhydrite near Base of Upper Unit of Wymark Member - Duperow Formation.	-	(in pocket)
Figure 24 -	Geochemical Profile of the Dinsmore Evaporite of the Wymark Member -		

		Duperow Formation.	- (in pocket)
Figure 25	-	Geochemical Profiles of Anhydrites in Unit A of the Seward Member - Duperow Formation.	- (in pocket)
Figure 26	-	Sample Computer Print-Out Sheet Illustrating Manner of Recording Results.	-after page 223
Figure 27	-	Calibration Curve for Strontium.	after page 225
Figure 28	-	Isopach Map of the Interval between the Top of the Lower Member of the Birdbear Formation and the Top of the Souris River Formation.	
Plates	-	All plates follow -	
Table - 1	-	Nomenclature and Correlation Chart-after pages 7 and 126	
Table - 2	-	Anhydrite Classification.	- after page 115
Table - 3	-	Operating Conditions for X-ray Apparatus.	- page 224
Table - 4	-	Chemical Analyses of Mississippian Carbonates R-58 and R-59	- page 225
Table - 5	-	Results of X-ray Analyses	- page 231
Table - 6	-	Q Values Grouped according to Anhydrite Categories	- page 257


HUDSON BAY
ALBERTA
MANITOBA
SASKATCHEWAN
EDMONTON
PRINCE ALBERT
SASKATOON
CALGARY
REGINA
BRANDON
WINNIPEG
MONTANA
HELENA
BISMARCK
NORTH DAKOTA
SOUTH DAKOTA
PIERRE
WYOMING
Area of Report
100 0 100 200
SCALE IN MILES
Williston Basin boundary after Porter and Fuller (1959)

Figure 1

INTRODUCTION

General Statement

The first significant published regional study of the Devonian System in the subsurface of the Williston Basin was carried out by Baillie for his doctoral dissertation presented in 1952 to the Department of Geology, Northwestern University, Evanston, Illinois (published in 1953 and republished in 1955). In his study Baillie subdivided the Devonian System into four major stratigraphic units, in descending order:

Qu'Appelle Group

Saskatchewan Group

Manitoba Group

Elk Point Group.

He further subdivided the groups into formations some of which he named. One of these formations, the uppermost in the Saskatchewan Group, he correlated with the Nisku Formation of central Alberta and the name Nisku was applied to this unit. Considerable controversy has arisen concerning Baillie's proposed correlation. Meneley (1958) agreed with Baillie's correlation and called the Nisku interval of the Williston Basin a format. On the other hand, Belyea (1955, 1957) presented evidence to show that the Nisku interval of the Williston Basin and its equivalent in eastern Alberta is stratigraphically lower, and consequently older, than the Nisku Formation of the type area of central Alberta. Sandberg and Hammond (1958) working in the United States portion of the Williston Basin concurred with Belyea and proposed a new name, Birdbear Formation for the uppermost unit of the Saskatchewan Group. This name was later introduced into the nomenclature of the Canadian portion of the Williston Basin by Kents (1959) and has now become the official nomenclature for

the Nisku interval in Saskatchewan.

This writer is of the opinion that conclusive evidence has not been so far presented to indicate the true relationship between the Birdbear Formation and the Nisku Formation, because the previous workers did not adequately study the area of transition between the reef and shale basin environment of Alberta and the shelf sea environment of Saskatchewan, Montana and North Dakota.

Objectives of this Study

The purpose of this thesis is to give an account of various aspects of the geology of the Saskatchewan Group, including stratigraphy, sedimentology, and palaeontology, and to relate them to similar aspects in equivalent rocks in adjacent areas. The writer anticipates that by approaching the problem in this manner it will be possible to show the relationship between the Nisku and Birdbear Formations.

Methods and Procedures

In a subsurface study of this magnitude, it is necessary to become familiar with the lithologies of the various stratigraphic units in all parts of the area of study. However, because of the large number of wells in the map area (640 wells penetrate to the Saskatchewan Group not including all wells within field areas in Alberta), it would have been a monumental task to attempt to examine all lithologic data from each well, and the writer therefore, chose to examine the lithologic data from strategically located wells throughout the region of study. Well sample cuttings, from 73 of these wells were examined, further lithologic data were obtained from 98 lithologic logs prepared by American and Canadian Stratigraphic Services and from the author's personal ex-

amination of 102 cored intervals and 10 outcrop sections. The depths of formation and member boundaries were determined from the lithological and mechanical log data and were used to prepare isopach and structure contour maps. Some 565 thin sections of carbonate rocks and anhydrites were examined and 353 specimens of anhydrite were analyzed by x-ray fluorescence as aids to the discussion of the sedimentology.

All colours used in the rock descriptions of this thesis are taken from the Geological Society of America Rock Color Chart. For the sake of brevity and clarity all textural descriptions of non-clastic rocks used in this thesis were taken from Williams, Turner and Gilbert (1955, pp.276-277). Their classification is as follows:

Crystalline Granular	- Coarse, greater than 5.0 mm.
	- Medium, 1.0 to 5.0 mm.
	- Fine, 1.0 mm. to 0.2 mm.
Microcrystalline	- 0.01 mm. to 0.2 mm.
Cryptocrystalline	- less than 0.01 mm.

Area of Study

The area of study was chosen because it includes the region where the transition between the reef and shale basin and the shelf sea environments occurs. It includes approximately 150,000 square miles and straddles both the Saskatchewan-Alberta interprovincial boundary and the international boundary (Figure 1). The region is limited by the 106th meridian of longitude (3rd survey meridian) in the east, the 113th meridian of longitude in the west, the 46th parallel of latitude to the south and the 54th parallel of latitude to the north. Little consideration was given to the region northwest of a line extending from township 30 range 20 west of the 4th meridian to township 50 range 5 west of

the 4th meridian, since that area has been adequately covered by numerous workers. Of the 640 wells which penetrate the Saskatchewan Group in the map area approximately 400 pass through to the base of the Saskatchewan Group. However, about 153 of these are beyond the erosional limit of the Birdbear Formation or equivalents and penetrate an incomplete upper portion of the section.

Geological Setting

Rocks of the Devonian System are known to underlie most of the northern Great Plains. They are mainly of Middle or Late Devonian age, but local occurrences of Lower Devonian strata have been reported from southwestern Montana and northwestern Wyoming (Dorf, 1934).

Devonian rocks are exposed at the surface along the periphery of the northern Great Plains. In the east, in Manitoba, they lie along the edge of the Precambrian shield and are primarily Middle Devonian in age. As these outcrops are traced northwestward across Saskatchewan along the edge of the Precambrian shield they become slightly younger, and in northwestern Saskatchewan and northeastern Alberta the Devonian strata are mainly late Middle to early Late Devonian (Norris, 1963). On the western periphery, that is in the Cordilleran orogenic belt, the Devonian rocks exposed are primarily Late Devonian in age but some late Middle Devonian rocks have been found in the Jasper area of Alberta. Scholten and Hait (1962) reported Middle Devonian rocks in western Montana and eastern Idaho. There are two outcroppings of Devonian strata within the northern Great Plains area, both of Upper Devonian beds, in the Little Rocky Mountains and the Big Snowy Mountains (Figure 2). These are also the only Devonian outcroppings in the study area.

The Devonian rocks of the map area belong to the Middle and Upper Devonian Series and are superjacent to an unconformity which truncates progressively younger beds from west to east, beginning in the west with strata belonging to the Cambrian System through to rocks belonging to the Silurian System along the eastern side of the map sheet (Porter and Fuller, 1959, pp. 128-129). In the northern portion of the area of study the Devonian rocks are also truncated by an unconformity which cuts across progressively older beds from south to north (Figure 2). This unconformity is overlain by Cretaceous rocks. In the remainder of the area the overlying rocks are Mississippian, Jurassic, Cretaceous and Tertiary, in ascending order.

Structurally, the map area straddles the Sweetgrass - North Battleford Arch. Strata on the west side of the arch are on the east flank of the Alberta syncline and strata on the east side are on the north and west flank of the Williston Basin. Laramide intrusions, (Sweetgrass Hills, Bearpaw Mountains, and Little Rocky Mountains), epeirogenic rejuvenation of structural elements in the Precambrian basement, and post-Middle Devonian solution of the Devonian salt deposits have caused the Devonian and younger strata to be flexed into anticlinal, synclinal and monoclinal structures.

STRATIGRAPHY

Origin of the Stratigraphic Nomenclature

OUTCROP NOMENCLATURE

Isbister (1855) was the first worker to record the presence of rocks of Devonian age in western Canada. He concluded that fossils collected from the Athabasca and MacKenzie Rivers by Sir John Richardson belonged to "the epoch of the Marcellus shales (Author's note - rocks of Middle Devonian age) and associated limestones, of the New York Survey". Shortly after this Billings (in Hind, 1859) reported the occurrence of Devonian rocks from the Lake Winnipegosis and Lake Manitoba area. Later work by Tyrrell (1892) disclosed that these rocks belonged to the Middle Devonian and lower Upper Devonian Series. In 1858 and 1859, as a member of the Palliser Expedition, Sir James Hector examined limestone exposures which he considered to be either of Devonian or Carboniferous age. His findings were published in 1863. McConnell (1887) was the first to recognize stratigraphic units within the Devono-Carboniferous rocks of Hector (1863). He subdivided them into a number of formations including an Intermediate Limestone of Devonian age and a Lower Banff Limestone of Devono-Carboniferous age. Dowling (1908) considered the Lower Banff Limestone to belong to the Carboniferous System, leaving the Intermediate Limestone as the only formation of Devonian age in the Rocky Mountains. Kindle (1924) and Shimer (1926) both carried out detailed studies of the rocks originally subdivided by McConnell (1887). Kindle found he could not delineate the two units because of dolomitization and included both in the Banff limestone and dolomite. Shimer (1926), on the other hand, confined the use of the term Banff to rocks of Mississippian age and

placed the rocks of Devonian age in the Minnewanka Formation which he divided into two members.

Raymond (1930) working in the Jasper area delineated 6 formations in the following stratigraphic order:

Kiln Formation

Fiddle Formation

Coronach Formation

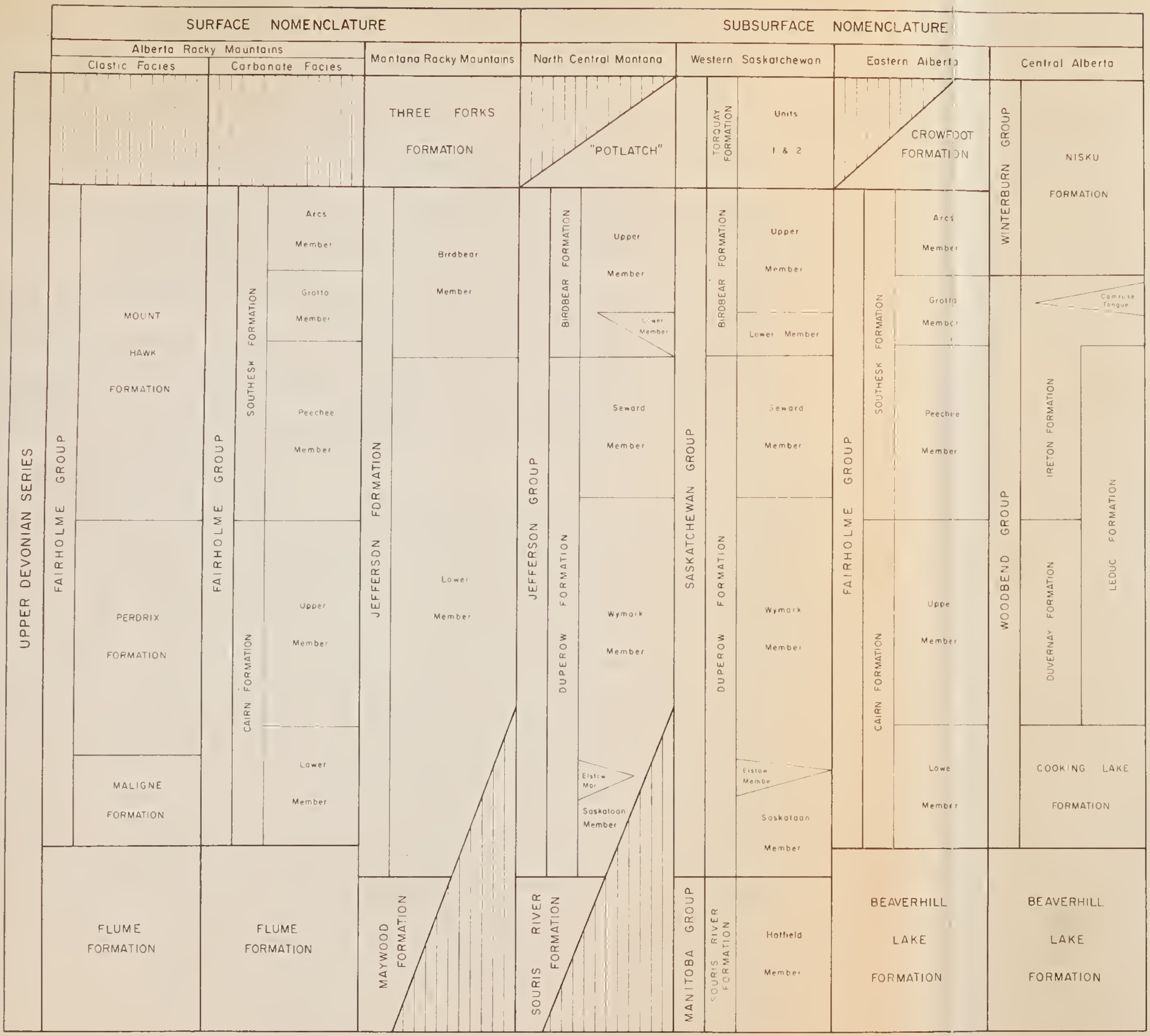
Boule Formation

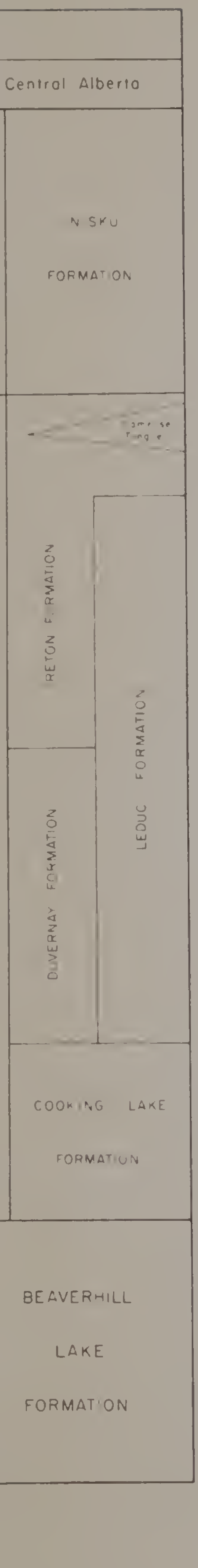
Perdrix Formation

Flume Formation.

However, it was later discovered that his Kiln and Coronach Formations were repeated sections of other formations resulting from faulting or folding. This observation made his four upper units invalid and resulted in recognition of only the lower two formations. In 1943 Beach mapping in the Moose Mountain-Morley areas of the Rocky Mountains gave formation status to the two members of the Minnewanka Formation. He called the lower member Fairholme Formation and the upper member Palliser Formation. DeWit and McLaren (1950) revised Beach's (1943) Fairholme Formation by removing the upper silty beds and called them the Alexo Formation. They also proposed the name Mount Hawk for the carbonates directly overlying the Perdrix Formation of Raymond (1930). DeWit and McLaren observed that the Fairholme could be divided into two members which they left unnamed. In 1955 McLaren noted a facies relationship between the non-argillaceous carbonates of the Fairholme Formation and the so-called clastic strata of the Mount Hawk, Perdrix and Flume Formations of the Athabasca river area. As a result of his observations, McLaren (1955) gave the Fairholme group-status and named

Table I


SURFACE NOMENCLATURE
SUBSURFACE NOMENCLATURE
Alberta Rocky Mountains
Clastic Facies
Carbonate Facies
Montana Rocky Mountains
North Central Montana
Western Saskatchewan
Eastern Alberta
Central Alberta
UPPER DEVONIAN SERIES
FAIRHOLME GROUP
MOUNT HAWK FORMATION
PERDRIX FORMATION
MALIGNE FORMATION
FLUME FORMATION
FAIRHOLME GROUP
SOUTHESK FORMATION
Arcs Member
Grotto Member
Peechee Member
CAIRN FORMATION
Upper Member
Lower Member
FLUME FORMATION
THREE FORKS FORMATION
JEFFERSON FORMATION
Birdbear Member
Lower Member
MAYWOOD FORMATION
"POTLATCH"
JEFFERSON GROUP
BIRDBEAR FORMATION
Upper Member
Lower Member
DUPEROW FORMATION
Seward Member
Wymark Member
Elstow Mbr
Saskatoon Member
SOURIS RIVER FORMATION
SASKATCHEWAN GROUP
TORQUAY FORMATION
Units 1 & 2
BIRDBEAR FORMATION
Upper Member
Lower Member
DUPEROW FORMATION
Seward Member
Wymark Member
Elstow Member
Saskatoon Member
MANITOBA GROUP
SOURIS RIVER FORMATION
Hatfield Member
CROWFOOT FORMATION
FAIRHOLME GROUP
SOUTHESK FORMATION
Arcs Member
Grotto Member
Peechee Member
CAIRN FORMATION
Upper Member
Lower Member
BEAVERHILL LAKE FORMATION
WINTERBURN GROUP
NISKU FORMATION
Camrose Tongue
WOODBEND GROUP
IRETON FORMATION
DUVERNAY FORMATION
LEDUC FORMATION
COOKING LAKE FORMATION
BEAVERHILL LAKE FORMATION



Central Alberta
NISKU
FORMATION
IRETON FORMATION
LEDUC FORMATION
DUVERNAY FORMATION
COOKING LAKE
FORMATION
BEAVERHILL
LAKE
FORMATION

its former members Southesk and Cairn Formations. He also included the Athabasca river area formations within the Fairholme Group. Belyea and McLaren (1956) recognized three unnamed members in the Southesk Formation. In 1957 they called them:

Arcs Member

Grotto Member

Peechee Member.

They also noted that the Cairn was divisible into an upper and a lower member. Taylor (1957) restricted the name Flume Formation to the lower member of Raymond's (1930) Flume and called the upper member Maligne Formation. Local changes in nomenclature have been made by Mountjoy (1965) and Price (1964, 1965), but for the most part the terminology presented in Table I is accepted for the surface exposures in the Alberta Rocky Mountains.

The nomenclature of the Devonian exposures, in Montana, has not undergone as extensive a metamorphosis as has the terminology in westwen Canada. Peale (1893) named and described the Devonian rocks of the Three Forks, Montana area, calling the units Three Forks and Jefferson, youngest to oldest. This nomenclature was later applied by various workers to all outcroppings of Devonian rocks in Montana. Sloss and Laird (1947) employed an informal subdivision of these units and Wilson (1955) was the first to apply the subsurface Williston Basin terminology to the surface sections. Sandberg and Hammond (1958) working in the Williston Basin in North Dakota carried the Duperow and Birdbear nomenclature west to the surface section in the Little Rocky Mountains. Sandberg (1965) has since dropped the use of the term Duperow from the lower part of the Jefferson Formation since he feels that this part of

the succession can be further subdivided. The terminology presently applied to the Montana outcrop section is that presented in Table I.

SUBSURFACE NOMENCLATURE

Since the area of study includes parts of three separate political subdivisions, the subsurface nomenclature differs to some extent, although the Upper Devonian rocks of this map area were for the most part laid down under similar environmental conditions. Prior to 1947 when oil was discovered in the reefs of Upper Devonian age in the Leduc area of Alberta, the nomenclature applied to Upper Devonian rocks in the few scattered deep boreholes in western Canada was generally taken from the Montana outcrops, e.g. Jefferson and Three Forks Formations. However, following the establishment of a nomenclature for the Upper Devonian strata of the Leduc area (Geological Staff of Imperial Oil Ltd., 1950), these names were applied to the beds of Upper Devonian age in eastern Alberta and Saskatchewan. In 1951 Andrichuk published a regional study of the rocks of Devonian age in an area including Montana and parts of Wyoming, Alberta and Saskatchewan. He subdivided the strata into four units which were suitable for his analysis of the succession, and added much to the knowledge of the regional stratigraphy and sedimentation of the area. However, because of their informal nature and the difficulty encountered in correlating them, Andrichuk's terms did not enjoy widespread usage. Powley (1951) presented a subdivision of the Devonian strata of central Saskatchewan; he delineated 6 stratigraphic units;

Moose Jaw Group

Duperow Formation

Hudson Bay Formation

Winnipegosan Formation

Elm Point Formation

Ashern Formation.

The top two units include much of that portion of the succession of interest in this study. Baillie (1953, 1955) recognized a somewhat different subdivision of the Devonian System of the Williston Basin and included Powley's (1951) upper three units in his Manitoba, Saskatchewan and Qu'Appelle Groups. The boundary between Middle and Upper Devonian rocks was found to be somewhere within the Manitoba Group. Baillie's group and formational subdivisions were based on the lateral persistence of thin shaly beds which could be employed as marker horizons.

The discovery of oil in Mississippian beds of the Williston Basin stimulated interest in that area as an oil province and with this increased interest attempts were made to standardize the nomenclature of the area. The result was the establishment of the Williston Basin Nomenclature Committee, organized under the Paleozoic subcommittee of the American Association of Petroleum Geologists Geologic Names and Correlations committee. In spite of the fact that the findings of this group were never published, many of the names which were proposed are now commonly used. Stanton (1953) introduced some of the names proposed by the nomenclature committee and a more formal introduction (including standard subsurface reference sections) was made by the North Dakota Geological Society in 1954. Among definitions in use which arose from findings of this committee is that of the Duperow Formation which name was applied to Baillie's (1953, 1955) unnamed unit in his Saskatchewan Group. This name was an unfortunate choice, the result of misunderstanding of Powley's (1951) definition, since the Duperow Formation of the committee

includes only the uppermost three units of Powley's Duperow Formation.

Sandberg and Hammond (1958) proposed a standard subsurface reference section for rocks of Late Devonian age in the Williston Basin. This reference section was located in the Mobil Oil Producing Co. No. 1, Birdbear well (C SE$\frac{1}{4}$ NW$\frac{1}{4}$-22-149N-91W) in Dunn Co., North Dakota. Besides changing Baillie's (1953, 1955) Nisku Formation to Birdbear Formation, they also proposed the name Jefferson Group for the interval previously called Saskatchewan Group. Kent (1963) in a regional study of the Saskatchewan Group in southwestern Saskatchewan found that the Duperow Formation was divisible into three lithologically distinct stratigraphic units:

Seward Member

Wymark Member

Unnamed Basal Member.

Kent (1965) attempted to illustrate the relationship between the stratigraphic units proposed in southwestern Saskatchewan and those in general use in southeastern Alberta. The terminology which is applied to the units of the Saskatchewan Group, in this paper, are presented in Table I.

The nomenclature employed for Upper Devonian strata in eastern Alberta is in a somewhat confused state. The Montana outcrop terminology (Three Forks and Jefferson Formations) formerly was widely used, but in 1957 Belyea and McLaren proposed that the nomenclature which they had applied to the surface exposures in the Rocky Mountains also be utilized in the subsurface of southern Alberta. The stratigraphic names of Belyea and McLaren are used most often at the present time, nevertheless they have not received official sanction, with the result

that a variety of other names also are applied to the same strata. Furthermore, it was pointed out by Kent (1965) that there is a facies change within the Fairholme Group in eastern Alberta, and where this change occurs the nomenclature employed in southwestern Saskatchewan becomes more applicable. The stratigraphic terminology used for eastern Alberta in this study is that of Belyea and McLaren (1957), but the marker horizons which delimit the stratigraphic units of the Saskatchewan Group do not everywhere coincide with the boundaries of Belyea and McLaren's (1957) units, consequently the author has given the map units delineated by these marker horizon less formal names, for reference sake.

General Stratigraphy

UNDERLYING BEDS

In western Saskatchewan, the Saskatchewan Group is underlain by the Manitoba Group of Middle to Late Devonian age, and the Manitoba Group in turn, is superjacent to the Elk Point Group over most of the same area. However, in southwestern Saskatchewan the Manitoba Group oversteps the Ordovician Bighorn Group (Porter and Fuller, 1959) in such a manner that in extreme southwestern Saskatchewan, only the upper beds of the Souris River Formation of the Manitoba Group are present.

Throughout the Elk Point, Manitoba and Saskatchewan Groups there is a general repetitive nature to the lithologies, reflecting alternating environments of deposition. These repetitive sequences are used to some degree as the basis for the stratigraphic divisions within this part of the succession. Each unit consists of shale, carbonate and evaporite, and the most complete examples are the Elk Point Group, the

Dawson Bay Formation (Lane, 1959), and the Davidson Member of the Souris River Formation (Lane, 1964). For example, in the Dawson Bay Formation, Lane (1959) outlined the following sequence: variegated red-green shale, passing upward into four successive varieties of carbonate and terminating in evaporite.

The alternating sequences within the upper part of the Souris River Formation become thinner and hence more numerous in a given thickness of strata. They are usually less perfectly developed than the underlying ones in that they commonly lack shales. These alternating lithologies are also found in the Duperow Formation and again the shales are generally absent.

Souris River Formation. The name Souris River Formation was first applied by the Williston Basin Nomenclature committee to the unnamed strata overlying the Dawson Bay Formation in the Manitoba Group of Baillie (1953, 1955). However, no standard reference section was established for this formation for the Williston Basin until 1958, when Sandberg and Hammond defined the Souris River Formation as those strata between 10,743 feet and 11,046 feet in the Mobil Producing Co. No. 1 Birdbear well (C SE¼ NW¼-22-149N-91W) Dunn Co., North Dakota. The Souris River Formation as presently defined in the subsurface of Saskatchewan was found to be a direct correlative of the strata in the standard subsurface reference section (Lane, 1964, Plate VII).

The Souris River Formation underlies all of western Saskatchewan and extends beyond its eastern, western and southern limits. In the north it is limited by its subcrop, the limit of which is slightly north of the map area. To the south the Souris River Formation becomes part of the Maywood Formation (Sandberg, 1961; Sandberg and Hammond, 1958)

and in the west it becomes part of the Beaverhill Lake Formation (Figures 3, 4, 5, and 6). The Souris River Formation thickens from 300 feet near the international boundary to about 600 feet near the limit of the overlying Duperow Formation in the north (Figure 2). It continues to thin southward along with the Maywood Formation and westward along with the Beaverhill Lake Formation. In the Front Range of the Rocky Mountains the Beaverhill Lake Formation is less than 100 feet thick.

The lower contact of the Souris River Formation is coincident with the top of the Dawson Bay Formation and is at the base of a relatively thin and persistent variegated red-green shale bed often identified as the "First Red Beds". Because of its persistence over much of the Williston Basin and its consistent stratigraphic position this shaly zone is an extremely good correlation marker. The top of the Souris River Formation is at the top of a gray argillaceous limestone or marlstone and coincident with the base of the Duperow Formation. This argillaceous zone is also persistent over the Williston Basin area, and is readily identifiable on mechanical logs, in well sample cuttings and in cores. The contact between these argillaceous strata and the overlying non-argillaceous beds of the Duperow Formation is gradational. Therefore, for the sake of consistency in determining the top of the Souris River Formation the author has tried to always choose the point at which there is marked change in lithology as characterized by the mechanical logs. Porter and Fuller (1962) showed that when traced to the west the top of the Souris River Formation can be identified as a highly argillaceous bed about 100 feet below the top of the Beaverhill Lake Formation. This bed is well developed in the core of the Calstan Fort Pitt No. 1-25 well (Lsd. 1-25-54-26W3) (Figure 8). All correlations made by the writer (Figures

3 to 6 inclusive) into Alberta agree with the findings of Porter and Fuller (1962).

Lane (1964) divided the Souris River Formation into three members:

Hatfield Member

Harris Member

Davidson Member.

The lower and middle members are characterized to some degree by the alternating lithologies which were previously discussed. The Hatfield Member may be considered to consist of two parts, the lower consisting of non-argillaceous carbonates and evaporites and the upper of interbedded shales or argillaceous limestones and non-argillaceous, fine-grained, fossiliferous limestones. To the south, in Montana, the rock types of the Souris River Formation grade laterally into the thin-bedded argillaceous dolomites of the Maywood Formation. Lithologically, the Souris River and Beaverhill Lake Formations are similar over most of southern Alberta, but in the Edmonton area there is a facies change in the Beaverhill Lake Formation, to an alternating sequence of argillaceous and non-argillaceous carbonates.

Lane (1964) proposed that the boundary between the Middle Devonian Series and Upper Devonian Series was at or near the top of the Harris Member. The Souris River Formation therefore would be mainly Middle Devonian in age, which is an accord with Walker (1958) but disagrees with Baillie (1953, 1955) who suggested that the Souris River Formation was early Late Devonian in age. The stratigraphic equivalents of the Souris River Formation, the Maywood Formation and the Beaverhill Lake Formation in Alberta are also considered to be of late Middle to

early Late Devonian age (Sandberg, 1961; Crickmay, 1957). However, Norris (1963) suggests that the Waterways (Beaverhill Lake) Formation maybe entirely early Late Devonian in age.

SASKATCHEWAN GROUP

The Saskatchewan Group is superjacent to the Manitoba Group, and is the thickest major stratigraphic unit within the Devonian System of the Williston Basin. In the area of study it attains a maximum thickness of 1100 feet near the 110th meridian of longitude. It thins eastward to about 800 feet at the 106th meridian of longitude and to about 500 feet to the south and north. West of the arbitrary cut-off (Figure 2) it becomes part of the Fairholme Group which thickens to about 1300 feet in the vicinity of the southern Alberta Marginal Reef Complex. North of township 37, between the 106th and 111th meridians of longitude, the Saskatchewan Group is truncated by pre-Cretaceous erosion and subcrops against the base of the Lower Cretaceous Mannville Formation (Figure 2). The Montana equivalent of the Saskatchewan Group, the Jefferson Group, is also truncated, but this is due to pre-Mississippian erosion. The subcrop pattern of this truncation is found in the southeast portion of the map area (Figure2).

The basal contact of the Saskatchewan Group coincides with the top of the Souris River Formation, and when the basal unit of this group is traced westward it is found to include the upper beds of the Beaverhill Lake Formation. The upper contact in the area south of the subcrop is easily identified on mechanical logs as a marked lithologic change from the non-argillaceous carbonates of the Birdbear Formation to the very argillaceous beds of the Three Forks Group. However, when this upper contact is examined in cored intervals it is gradational and is

more difficult to identify. The author has always tried to pick the top of the Saskatchewan Group at the first "clean" (non-argillaceous) carbonate.

The two main stratigraphic units within the Saskatchewan Group, the Duperow and Birdbear Formations, are lithologically similar, but can be distinguished from one another by marker horizons. The Duperow Formation is composed of four members: the basal Saskatoon Member of non-argillaceous carbonates (mainly limestones) and minor evaporites; the Elstow Member consisting of very argillaceous carbonates and marlstones; the Wymark Member, a thick sequence of non-argillaceous carbonates (both limestones and dolomites) interbedded with thin evaporites and minor argillaceous beds; and the Seward Member made up of highly argillaceous carbonates interbedded with thin evaporites and non-argillaceous limestones and dolomites.

The author has divided the Birdbear Formation into two members: a lower member composed of non-argillaceous limestones and dolomites over most of the area and an upper member which is predominantly dolomite with some interbedded evaporites. However, near the top of the lower member is a thin bed which, though only slightly argillaceous over the southern part of western Saskatchewan, becomes thicker and increasingly more argillaceous to the west and north, with the result that the lower member of the Birdbear becomes a thick sequence of argillaceous carbonates in the central portion of the map area.

There are a number of zones rich in the sporomorphs Tasmanites and Leiosphaeridia (Kent, 1963, 1965) in the Duperow and Birdbear Formations. Using these zones as aids to correlation Kent (1965) traced the members of these formations westward into southeastern Alberta until it

became obvious that the divisions of the Saskatchewan Group were no longer valid. At this point an arbitrary cut-off was established, and in this thesis the cut-off has been extended northward as far as the edge of the map sheet (Figure 2). West of the cut-off the stratigraphic subdivisions for the Fairholme Group are more applicable and east of it those of the Saskatchewan Group are easily recognized.

OVERLYING BEDS

Three Forks Group The beds superjacent to the Birdbear Formation were laid down during the closing stages of Devonian time in the Williston Basin area. These strata have been variously called the Qu'Appelle Group by Baillie (1953, 1955), the Three Forks Formation by Kents (1959) and most recently the Three Forks Group by Christopher (1961). Kents (1959) proposed a two-fold division of the Three Forks Formation, correlated it with the Wabamun Group of Alberta and applied the names Stettler and Big Valley Members (oldest to youngest) to his divisions. Christopher (1961), on the otherhand, raised the Three Forks to a group and included the superjacent Bakken Formation in the group. He also changed the name of the Stettler to the Torquay Formation.

The Torquay Formation of Christopher (1961) directly overlies the Birdbear Formation. It is found throughout western Saskatchewan south of its limit (Figure 2), but in the vicinity of townships 30 to 34 ranges 21 to 28 west of the 3rd meridian it loses its typical lithologies of red argillaceous carbonates and brecciated anhydrite and becomes mainly anhydritic. In general the Torquay Formation thickens toward the north from about 60 feet at the international boundary to 130 feet near its sub-crop edge. Christopher (1961) recognized six lithologic units within the Torquay Formation. These each consist of one or more of the following

rock types: greenish gray to grayish red shales, yellowish gray to reddish brown dolomites and white anhydrites. Units 1, 2, 4, 5 and 6 very commonly contain strongly brecciated dolomite and anhydrite beds which Christopher interpreted as representing regoliths. Many of the regoliths are locally developed; however, Christopher found that one in unit 2 is very widespread and can be identified at many locations in eastern Saskatchewan.

The Torquay Formation is overlain by the green chloritic marine shales of the Big Valley Formation. The shales are greenish gray to grayish green, non-calcareous, finely fissile and have a waxy lustre. Kents (1959) reported the presence of a thin biostromal limestone which appears to rise stratigraphically in the formation in a westerly direction. Christopher (1961) attributed this apparent rise of the limestone to removal by erosion of the upper shales of the Big Valley Formation toward the west.

The Big Valley Formation is overlain by the Bakken Formation the sediments of which probably mark the end phase of Devonian sedimentation and the commencement of Mississippian sedimentation in the Williston Basin area. The Bakken Formation lies disconformably on the Big Valley Formation (Christopher, 1961; Kents, 1959). It consists of a middle sandstone unit overlain and underlain by black shales.

The Three Forks Group is thought to be correlative with the Three Forks Formation of the type area as originally defined by Peale (1893) (Christopher, 1961). Brindle and Guliov (1965) proposed that the Big Valley Formation of western Saskatchewan correlates with the upper part of the Three Forks of Montana and with the green shales below the Exshaw Formation in the subsurface of the Alberta plains. The Torquay

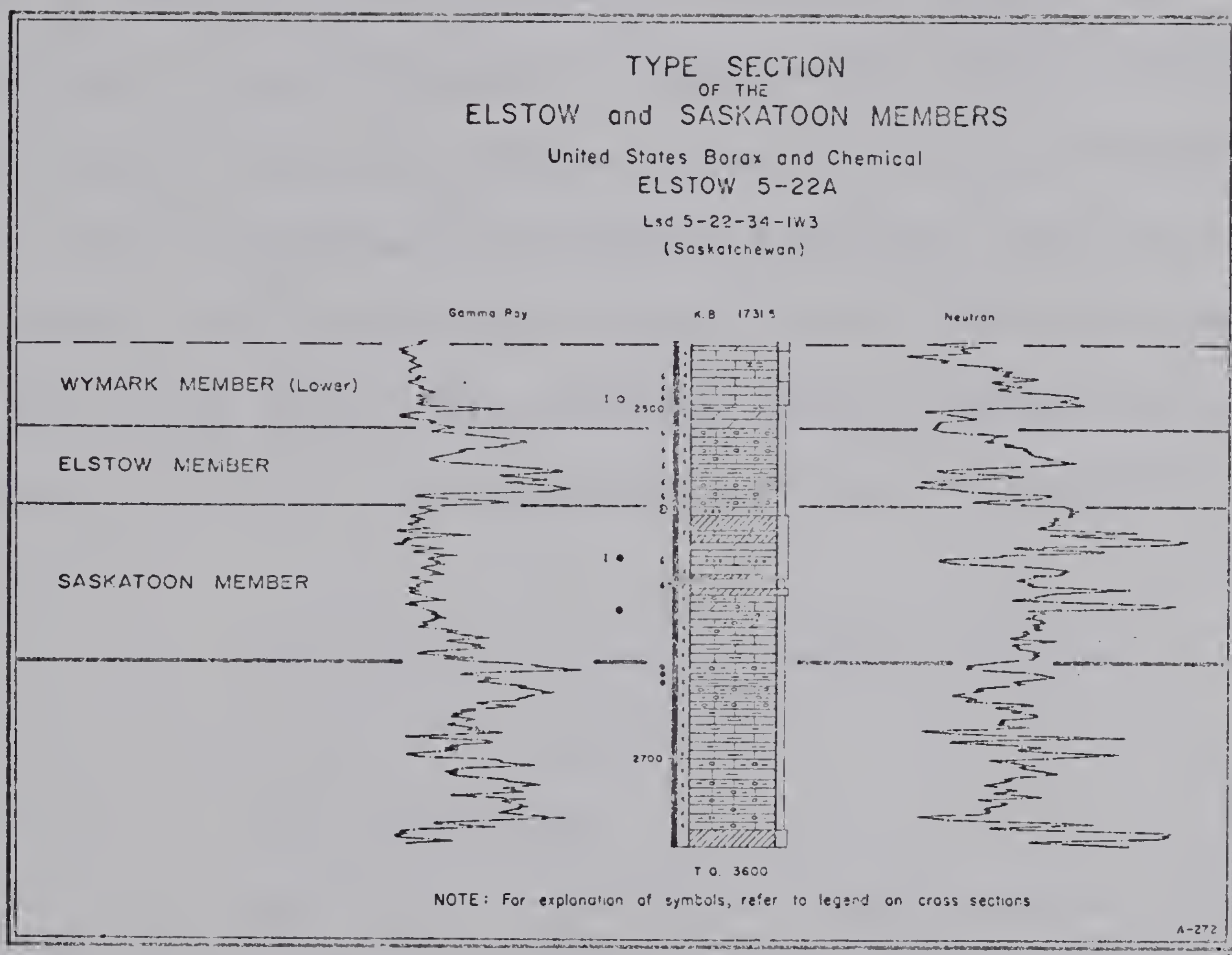


Figure 10

Type Section of the Saskatoon and Elstow Members of the Duperow Formation

Formation is probably correlative to the Stettler Formation of the Wabamun Group and the upper beds of the Winterburn Group.

Detailed Stratigraphy

DUPEROW FORMATION

Saskatoon Member   The name Saskatoon Member is proposed here for the sequence of carbonate rocks previously described by Kent (1963) as the carbonate unit of the basal member of the Duperow Formation. The member directly overlies the Hatfield Member of the Souris River Formation and underlies the Elstow Member of the Duperow Formation. The type section of the member is designated as the interval between 2556.5 feet and 2644.3 feet in the United States Borax and Chemical Company (hereinafter abbreviated to U.S.B. & C.) Elstow 5-22A well (Lsd. 5-22-34-1W3) (Figure 3).

Type Section: Saskatoon Member (new name)

U.S.B. & C. Elstow 5-22A

Lsd. 5-22-34-1W3

Name derived from city of Saskatoon about 30 miles northwest of the type well.

Interval: 2556.5 feet - 2644.3 feet

Lithology

Drilled Depth in feet	Overlying Beds - Elstow Member Section completely cored
2556.5-2558.9	Limestone - yellowish gray; microcrystalline; fossiliferous fragmental in part, mainly ostracods; thinly bedded with carbonaceous material along

bedding surface; dolomitic in part; sporomorphs are present.

2558.9-2560.0	Limestone - moderate yellowish brown; microcrystalline; some recrystallized fossil remains possibly bryozoa; poorly bedded; fair intergranular porosity; dolomitic.
2560.0-2561.3	Limestone - variable colouration from light gray to pale yellowish brown, to moderate yellowish brown; microcrystalline; pelletoidal in part with pellets ranging 0.26 to 0.42 mm. in diameter and ovoid to irregularly-shaped; carbonaceous material along bedding planes; poor porosity.
2561.3-2570.7	Anhydrite - moderate yellowish brown; microcrystalline to cryptocrystalline; vitreous to cloudy appearance; massive; sharp contacts with overlying and underlying beds.
2570.7-2572.5	Dolomite - very pale orange; microcrystalline; thinly bedded with carbonaceous material along bedding surfaces; slightly argillaceous; fair intergranular porosity.
2572.5-2577.3	Anhydrite - mottled light gray and dark brown; microcrystalline; vitreous to cloudy appearance; massive; dolomitic in part, becomes very dolomitic in lower portion.

2577.3-2585.5	Dolomite - moderate yellowish brown; microcrystalline, sucrosic; thinly-bedded with carbonaceous material along bedding surface; fair intergranular porosity.
2585.5-2593.0	Limestone - yellowish gray; microcrystalline to cryptocrystalline; fossiliferous fragmental, unidentifiable fossil remains; thin pelletoid bed between 2588.9 feet and 2590.1 feet - pellets range from 0.17 to 0.64 mm. in diameter, irregularly shaped; poorly bedded with some carbonaceous material along bedding surface; scattered dark brown anhydrite porphyroblasts; fair intergranular porosity.
2593.0-2595.3	Limestone - very pale orange; microcrystalline; scattered brachiopod remains; thinly bedded with carbonaceous material along bedding planes; fair intergranular porosity.
2595.3-2597.5	Anhydrite - moderate yellowish brown; microcrystalline; vitreous appearance; mainly massive, but with some interbeds of very pale orange, microcrystalline dolomite.
2597.5-2602.5	Limestone - yellowish gray; microcrystalline; upper 4 feet pelletoidal with ovoid to irregularly shaped pellets 0.17 to 0.34 mm. in diameter; lower 1 foot has scattered brachiopod fragments; massive;

	blebs of clear to bluish, cloudy anhydrite.
2602.5-2603.8	Dolomite - yellowish gray; microcrystalline, sucrosic; thinly-bedded with carbonaceous material along bedding surface; fair intergranular porosity.
2603.8-2607.8	Anhydrite - white to moderate yellowish brown; microcrystalline; cloudy appearance; thin beds of pale yellowish brown, microcrystalline; dolomite.
2607.8-2619.1	Limestone - yellowish gray; microcrystalline; most beds have only scattered fossil remains but there are intermittent concentrations of fossil material; mainly massive but with some sedimentary boudinage, where sedimentary boudinage is present there is a heavy concentration of carbonaceous material; dolomitic; poor to fair intergranular porosity.
2619.1-2619.6	Limestone - yellowish gray; microcrystalline; angular and subangular carbonate rock fragments; probably represents an intraformational breccia.
2619.6-2625.0	Limestone - yellowish gray; microcrystalline; scattered fossil remains for the most part but with intermittent concentration of fossil fragments; mainly massive but with some sedimentary boudinage and associated high concentration of carbonaceous material; dolomitic; poor to fair intergranular porosity.

2625.0-2635.1	Limestone - yellowish gray; microcrystalline; fossiliferous fragmental mainly crinoid columnals; sedimentary boudinage in part to poorly bedded, carbonaceous material along bedding surface and associated with sedimentary boudinage; slightly argillaceous; poor porosity.
2635.1-2644.3	Limestone - light gray; microcrystalline; thinly bedded, slightly argillaceous; fair intergranular porosity.
	Underlying Beds - Hatfield Member - Souris River Formation.

The Saskatoon Member underlies most of western Saskatchewan. It is limited in the north by pre-Cretaceous erosion and in the south it thins due to transgressive onlap of older Devonian, Ordovician and Cambrian rocks subcropping in the central Montana uplift. In southern Alberta, the Saskatoon Member becomes the basal part of the Cairn Formation and the upper beds of the Beaverhill Lake Formation. The Member also extends for some distance beyond the eastern limits of the study area. However, in the vicinity of the International boundary in the southeast corner of western Saskatchewan, it becomes difficult to separate the lower three members of the Duperow Formation. This arises from the change in facies which the Elstow Member undergoes in this region.

The Saskatoon Member appears to be conformable with the underlying and overlying strata. But, locally, it may be disconformable with the subjacent Souris River Formation, since a 1½ foot thick breccia was observed at this contact in the core from the Sohio Standard Langham No.1

well (Lsd. 9-18-40-7W3). This basal contact is readily chosen on mechanical logs (particularly the gamma ray curves) and identified as the point at which there is a change from the highly argillaceous strata of the Souris River Formation to the less argillaceous beds of the basal part of the Saskatoon Member. The upper contact with the Elstow Member can be recognized over most of western Saskatchewan with the exception of the southeast corner and northwest corner along the Alberta-Saskatchewan interprovincial boundary where the Elstow changes facies to non-argillaceous carbonates.

The Saskatoon Member thickens regionally in a northwesterly direction. It is thinnest in the southeast portion of the map area, where it ranges between 40 and 50 feet thick. It attains a maximum thickness in the Wainwright area of Alberta where it is about 200 feet thick.

Lithologically, this member resembles the lower carbonate unit of the Cooking Lake Formation (Andrichuk, 1958). It consists mainly of carbonate rocks varying from pale yellowish brown to yellowish brown, microcrystalline limestones, dolomitic limestones and dolomites. Ovoid to irregularly-shaped spherites [1](pellets, oolites or superficial oolites) having diameters ranging between 0.1 mm. and 0.6 mm. are common, particularly along the eastern and western sides of the map area (Figure 11).

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[1](Author's footnote) The term spherite is employed throughout this chapter because of the difficulty of distinguishing between pellets, oolites and superficial oolites, in hand specimens. Consideration will be given to differentiating among these spherites in the sedimentation portion of this thesis (p. 130).

Fragmented brachiopods and crinoid columnals are the main organic remains found. They are usually intermixed with the oolitic material. Commonly the carbonate rocks in the upper 30 feet of this unit are interbedded with dusky yellowish brown to pale yellowish brown, microcrystalline anhydrites. The evaporite deposits are most prominent in the central portion of the area of study (Figure 12). Near the Alberta-Saskatchewan interprovincial boundary the strata underlying the anhydrites become argillaceous and the argillaceous content increases westward. In Alberta these argillaceous beds are included in the upper portion of the Beaverhill Lake Formation. Where first encountered in Saskatchewan (Figures 11 and 12) these beds are pale yellowish brown to yellowish gray, microcrystalline to cryptocrystalline, slightly argillaceous limestones and dolomitic limestones, but they grade westward to yellowish gray, light gray and olive gray, highly argillaceous limestones and dolomitic limestones and interbedded light gray to greenish gray, calcareous shales. In the interbedded carbonate-shale sequences the thin carbonate beds commonly show the effects of post-depositional compaction in the form of pinch and swell structures described by McCrossan (1958) as sedimentary boudinage. These argillaceous strata are generally highly fossiliferous with brachiopod remains and crinoid columnals the most common organic material. The fossils in the carbonate beds are ordinarily highly comminuted, but in the shales they are well preserved. In the Calstan Fort Pitt No. 1-25 well (Lsd. 1-25-54-26W3) the lower beds of the argillaceous portion of the Saskatoon Member contain about 6 beds each 1 to 2 inches thick, of well-rounded, flattened, limestone pebbles, which are often mixed with fossil fragments. The pebbles usually have a black outer surface probably due to finely disseminated pyrite. In one of these

beds the black pebbles and finely comminuted organic debris are seen to form part of the fill material in a labyrinth of burrows (Plate 7 - No.1). The significance of these beds is discussed in a later section (p. 90). It is difficult to ascertain whether they are local developments or whether they have a more regional extent, since they can only be observed in cored intervals, being much too thin to be recognized in well cuttings.

Near the top of the Saskatoon Member there is a persistent sporomorph zone which has been used as a correlation marker horizon by the writer. This zone can be traced throughout western Saskatchewan and westward into eastern Alberta (Figures 3, 4 and 5).

Elstow Member The Elstow Member is defined here as those strata which occupy the interval between 2511.1 feet and 2556.5 feet in the U.S.B. and C Elstow 5-22A well (Lsd. 5-22-34-1W3) (Figure 10). It was formerly called the upper argillaceous unit of the unnamed basal member of the Duperow Formation (Kent, 1963).

Type Section: Elstow Member (new name)

U.S.B. & C. Elstow 5-22A

Lsd. 5-22-34-1W3

Name derived from village of Elstow

10 miles north of the type well.

Interval: 2511.1 feet - 2556.5 feet

Drilled Depth in feet	Overlying Beds - Wymark Member Section cored throughout
2511.1-2537.4	Limestone - pale yellowish brown to yellowish gray and light olive gray; microcrystalline to cryptocrystalline; brachiopods common; sedimentary

	boudinage with medium gray shale in internodular areas.
2537.4-2540.3	Shale - light gray; calcareous; flaky; very fossiliferous (mainly unidentifiable comminuted remains).
2540.3-2556.3	Limestone - pale yellowish brown to yellowish gray and light olive gray; microcrystalline to cryptocrystalline; brachiopods common; sedimentary boudinage with medium gray shale in internodular areas.
	Underlying Beds - Saskatoon Member.

The Elstow Member directly overlies the Saskatoon Member and is conformable with it. The contact between these two members is gradational and is usually chosen at the base of the lowest argillaceous bed. The member is subjacent to the Wymark Member and the contact between them is also conformable and gradational. It is chosen at the top of the first highly argillaceous bed.

This member has a northeast-southwest trending areal distribution within the map area. It is absent in central Montana, southeastern western Saskatchewan and in northeastern Alberta due to a change in facies from argillaceous carbonates to non-argillaceous carbonates. It is limited in the north by truncation caused by pre-Cretaceous erosion (Figure 2). To the west in southern and central Alberta the Elstow Member becomes the middle argillaceous unit of the Cooking Lake Formation (Figures 3, 4, 5 and 6), but the name Elstow is limited to the area east of the arbitrary

cut-off. This member can be traced eastward beyond the limits of the map area, and is present as far east as the Manitoba-Saskatchewan interprovincial boundary with the exception of southeastern Saskatchewan where it has lost its argillaceous character.

The Elstow Member is 45 feet thick at the type well. It thins to about 12 feet or less before it changes facies along the international boundary between Saskatchewan and Montana. Its axis of maximum thickness is in central western Saskatchewan and it thins slightly in all directions from this location. The maximum thickness of the unit in this region is 60 feet.

The lithologies of the Elstow Member include pale yellowish brown to olive gray and light gray, thinly-bedded, argillaceous and non-argillaceous limestones interbedded with medium light gray marlstones and greenish-gray to grayish-green, calcareous shales and hard mudstones. The limestones often exhibit well-developed pinch and swell structures when interbedded with soft, calcareous shales. Finely comminuted fossil fragments (Plate 1 No. 1) are common in the limestone beds and well preserved fossil remains are often found in the shaly beds. (It should be noted here that although these lithologies are undoubtedly present over much of the area, it is difficult to recognize them in well cuttings, since the shales are often washed out by the drilling mud. Therefore, where the lithologic data were obtained from well cuttings alone the lithology of the Elstow Member is represented as an argillaceous limestone.) In southwestern Saskatchewan the Elstow Member has a three-fold lithologic subdivision, consisting of argillaceous strata overlying and underlying a unit of 10 feet of non-argillaceous, pale yellowish brown, microcrystalline limestones or dolomitic limestones. For the most part dolomites and

dolomitic limestones are rare in this unit and have been observed at a few scattered locations.

In the regions where the Elstow Member changes facies it commonly grades into a sequence of carbonates in which the non-argillaceous beds are thicker and more numerous than the argillaceous strata. The section in the Calstan Fort Pitt No. 1-25 well (Lsd. 1-25-54-26W3) illustrates this gradual change (Figure 8). The core in this well shows that the beds at the same stratigraphic position as the Elstow Member consist of thick limestone beds containing stromatoporoids, tabulate corals and finely comminuted fossil debris. Thin shale partings and thin carbonate beds exhibiting sedimentary boudinage are all that remain of the Elstow lithologies. In the southwest the facies change is to an oolitic or pelletoidal carbonate.

Wymark Member The Wymark Member was named by Kent (1963), and was defined as the predominately non-argillaceous carbonate rocks which lie between the more argillaceous Elstow and Seward Members of the Duperow Formation.

The lower contact of the Wymark Member is coincident with the top of the Elstow Member. The upper contact was established by Kent (1963) at the base of the lowest argillaceous bed in the Seward Member. For the most part this makes the top of the Wymark Member coincident with the top of the Dinsmore Evaporite, an anhydrite which is mappable over a wide portion of western Saskatchewan and eastern Alberta.

The Wymark Member underlies most of western Saskatchewan, but in the north it is limited by pre-Cretaceous erosion. To the west it becomes part of the Cairn Formation. The member is present throughout northernmost central Montana, but is difficult to map further south in

the subsurface and surface exposures, because the lower contact which is recognized due to the change from argillaceous sediments of the Elstow Member to non-argillaceous strata in the Wymark Member is no longer discernible where the Elstow Member changes facies to a non-argillaceous carbonate.

The Wymark Member thickens regionally toward the west and northwest. The axis of maximum thickness trends east-west across the central portion of western Saskatchewan and the maximum thickness attained by the unit is about 580 feet near the Alberta-Saskatchewan interprovincial boundary west of Kindersley, Saskatchewan (Figure 13). It thins north and south from the area of maximum thickness and is thinnest in the area east of Saskatoon where it is about 185 feet thick. In northernmost central Montana it thins to about 240 feet before losing its identity as a mappable unit. Local anomalously thick and thin areas are present some of which can be attributed to salt removal or basement tectonics.

The writer has divided the Wymark Member into three informal units, lower, middle and upper. Each of these can be identified over much of western Saskatchewan. These units are distinguished by distinctive mechanical log markers, and make it easier to describe the stratigraphy of the carbonate rocks within the Wymark Member.

The lower unit comprises the lower 100 feet or less of the Wymark Member. The top of the unit is placed at the base of a sequence of slightly argillaceous carbonates which commonly overlies a thin persistent anhydrite bed (Figures 3 to 9 inclusive). Lithologically, the unit consists of pale yellowish brown to dark yellowish brown microcrystalline to cryptocrystalline limestones, dolomitic limestones and dolomites. Although the carbonates are mainly calcisiltite or calcilutite there are

local concentrations of limestone and dolomitic limestone composed entirely of euhedral calcite grains of fine-sand size. Through most of the unit there is little argillaceous material, but the lower 10 feet or more are generally slightly argillaceous and grade downward to the more argillaceous strata of the Elstow Member. The carbonate rocks are commonly fossiliferous, containing algae, brachiopods, crinoid columnals, some corals and other unidentifiable organic debris. Some pellet or oolitic beds are present and contain spherites ranging between 0.06 mm. and 1.67 mm. and averaging 0.3 mm. There are two main evaporite beds within this unit; one at the base and the other at the top. They are composed of pale yellowish brown to moderate yellowish brown, microcrystalline anhydrite. The anhydrites are particularly prominent in the central portion of the area of study although they do extend into southwestern Saskatchewan (Figure 12).

The lower 30 feet of the lower unit contain a sporomorph zone which has a wide lateral distribution. It has been recognized over most of western Saskatchewan and traced into southern Alberta where it is found in the middle of the lower member of the Cairn Formation.

The middle unit includes the middle 200 to 250 feet of strata within the Wymark Member. The top of this unit was placed at the base of a persistent but thin argillaceous bed (Figures 3 to 9 inclusive) which commonly overlies a thin anhydrite deposit.

Lithologically, the middle unit is somewhat similar to the lower unit of the Wymark Member. It is composed of dark yellowish brown to pale yellowish brown and rarely yellowish gray, microcrystalline to cryptocrystalline limestones, dolomitic limestones and dolomites. The dolomites are more prevalent in eastern Alberta where they grade westward into the dolomitized southern Alberta Marginal Reef Complex (Figure 12). Occurr-

ences of carbonate rock consisting entirely of euhedral calcite or dolomite grains increase significantly in this unit. This type of lithology is the dominant rock type in wells which penetrate the southern Alberta Marginal Reef Complex (Figures 4 and 12). Thinly laminated carbonates are another rock type which have local prominence. They consist of laminae of pale yellowish brown to moderate yellowish brown, microcrystalline to cryptocrystalline dolomitic limestone and dolomite alternating with black carbonaceous shale partings (Plate 1 Nos. 2 and 3). The carbonate rocks in these laminated sequences may rarely be slightly argillaceous; other slightly argillaceous beds are found at the base of the unit, but for the most part it is non-argillaceous. Pelletoidal or oolitic carbonates are commonly the predominant lithology in the middle unit. These beds generally comprise the entire thickness of this unit in some wells. The spherites are ovoid to globular, and rarely irregularly-shaped. They range between 0.07 mm. and 1.7mm. in diameter. Fossil debris is rarely intermixed with the spherites. The middle unit of the Wymark Member is relatively fossiliferous the fauna found includes, stromatoporoids, brachiopods, colonial and solitary corals, bryozoa and algal nodules and tubes.

Evaporite deposits are common in this unit particularly in west central Saskatchewan. The evaporites include pale yellowish brown to dusky yellowish brown, microcrystalline anhydrite and a 50 foot halite which was partially cored in the Husky Phillips Eatonia No. 1 well (Lsd. 4-32-26-24W3) (Figures 6 and 12). The anhydrites in this unit have thickness varying from less than 1 foot up to about 60 feet.

Near the base of the middle unit there is a persistent sporomorph zone which has been traced throughout western Saskatchewan and

into eastern Alberta where it is found at the base of the upper member of the Cairn Formation (Figures 3 to 9 inclusive). Another, but less significant sporomorph zone may be found about the middle of this unit.

The upper unit of the Wymark Member is 60 to 120 feet thick. The unit is dominated by evaporites of which The Dinsmore Evaporite at the top of the unit is the most important and widespread (Figure 12). There are parts of the study area where more than half of the upper unit consists of evaporites. For example, in the Imperial Dinsmore 1-32-27-11 well (Lsd. 1-32-27-11 W3) (Figure 3), there are approximately 60 feet of anhydrite in the 105 foot thick upper unit. Beyond the eastern limits of the map area the anhydrite locally changes facies to halite (Hutt, 1963, Plates B3b and B3c; Hutch, 1967). Where the Dinsmore Evaporite and the other anhydrite beds of the upper unit are not present, it is commonly due to a change in facies from anhydrite to carbonate rock. However, in the south Saskatoon area a breccia was observed in the U.S.B. & C. Elstow 5-22A well (Lsd. 5-22-34-1W3) occupying a stratigraphic position similar to that of the Dinsmore Evaporite. This breccia contains angular to subangular fragments of carbonate rocks in an extremely fine-grained matrix (Plate 9). The significance of this breccia is discussed in the chapter concerned with sedimentation (p.92). In association with the anhydrite beds are pale to dark yellowish brown and yellowish gray, microcrystalline to cryptocrystalline limestones, dolomitic limestones and dolomites. The limestones are most common along the eastern side of the area of study and in the south, whereas the dolomites predominate in eastern Alberta and toward the northwest (Figure 12). Unlike the middle unit there are few concentrations of euhedral calcite or dolomite grains in this unit, except in the vicinity

of the southern Alberta Marginal Reef Complex. In the east-central portion of the map area (Figure 12) the carbonates directly underlying the Dinsmore Evaporite have been metasomatically replaced to some extent by white, translucent, cryptocrystalline anhydrite usually as large blebs or beds. The carbonate rocks of this unit are somewhat more argillaceous than those of the underlying units. Pelletoidal and oolitic beds are less common than in the lower units of the Wymark Member, but those that are present vary little in general size and shape from those that were previously described. These strata also contain much less organic material; the biota consists of brachiopods, stromatoporoid colonies and algal nodules.

There is a sporomorph zone at the base of the unit, and although it is not as persistent as some of the lower zones it can be correlated over many parts of Saskatchewan. It is most useful as an aid in determining the base of the upper unit.

The stratigraphic subdivision of the Wymark Member discussed so far is valid in the southern portion of the map area, at least as far north as the limit of the Seward Member (Figure 2). However, north of this edge and east of range 14 west of the third meridian the Wymark Member becomes more argillaceous, as exemplified by the Sohio Standard Langham No. 1 well (Lsd. 9-18-40-7W3) (Figure 8) in which all of the middle Wymark and that portion of the upper Wymark not truncated by pre-Cretaceous erosion is composed of light medium gray to light gray, cryptocrystalline, very argillaceous limestones, and light medium gray to light gray, calcareous shales. Interbedded with these are non-argillaceous, pale yellowish brown to light gray, cryptocrystalline, limestones. Some of the non-argillaceous carbonates are laminated and are

similar to beds described from the middle unit further south. Only the lower unit of the Wymark Member retains its non-argillaceous nature in this area. Unfortunately, few wells penetrate the argillaceous facies of the Wymark Member and it is difficult to determine its limits. However, the author feels that the subcrop pattern of the Wymark Member may be employed to outline the distribution of the argillaceous strata in the Wymark Member. In the region north of the limit of the Seward Member and east of range 14 west of the 3rd meridian, the subcrop of the Wymark Member appears to be deeply eroded (Figure 2) probably because the rocks in this area were less resistent to erosion. On the other hand, the subcrop of the Wymark Member west of range 14 west of the 3rd meridian does not seem to be deeply eroded, probably because the rocks could withstand more weathering. Therefore the shaly phase of the Wymark Member is probably confined to the former region and the rocks of the latter area are probably non-argillaceous carbonates. The core and well cuttings of the British American Cutknife Rutley No. 13-14-43-22 well (Lsd. 13-14-43-22W3) and the Calstan South Battleford Province No. 3-16-42-17 well (Lsd. 3-16-42-17W3) indicate that the rocks in the Wymark Member west of range 14 west of the 3rd meridian are a thick carbonate sequence consisting of pale yellowish brown to yellowish gray, microcrystalline limestones, dolomitic limestones and dolomites. Some slightly argillaceous beds are present but the rocks are primarily non-argillaceous. Fossils are prominent, including brachiopods, branchiopods, crinoid columnals, pelecypods, ostracods, stromatoporoid colonies, and algal stromatolites. This thick non-argillaceous carbonate phase of the Wymark Member can be traced as far west as the southern Alberta Marginal Reef Complex (Figure 2).

Seward Member The Seward Member was named and described by Kent (1963). It is the predominantly argillaceous unit that lies between the non-argillaceous Wymark Member of the Duperow Formation and the Birdbear Formation. The Seward Member is everywhere conformable with the underlying Wymark Member, but there is probably an unconformity between the Seward and the superjacent Birdbear Formation in most of the eastern and southern parts of the study area. The base of the member is chosen at the base of a thin argillaceous limestone or greenish gray calcareous shale or mudstone which overlies the Dinsmore Evaporite. The upper contact is at the top of a moderately thick, locally variegated, red-green calcareous shale or mudstone or a gray argillaceous limestone. This uppermost shale or argillaceous limestone is a marker bed distinct on mechanical logs and can be correlated throughout the southern half of the map area.

This member retains its gross lithologic character well beyond the eastern limits of the region of study. It is limited in the north by truncation due to pre-Cretaceous erosion. In the west it changes facies to a non-argillaceous sequence of carbonates. The facies change is indicated by the Fairholme Group-Saskatchewan Group arbitrary cut-off (Figures 14 and15). Beyond the southern limits of the map area the Seward loses some of its argillaceous character, but the writer has recognized an alternating series of thin-bedded argillaceous and non-argillaceous rocks in at least two surface exposures (at Logan, Montana and in the Boulder River Canyon southeast of Livingstone, Montana) in the upper part of Sandberg's (1965) lower member of the Jefferson Formation. These strata occupy the same stratigraphic position as the Seward and are probably the southerly equivalent of this member. Figure 6 illustrates that the Seward Member is recognizable in the standard subsurface refer-

ence section Mobil Oil Producing Co. No. 1 Birdbear well (CSE ¼ NW¼-22-149N-91W) Dunn Co., North Dakota.

The isopach map (Figure 14) shows that there is a general regional east to west thickening of the Seward Member. As in the underlying units, this member has a thick trend across the central portion of the map area and thins somewhat to the north and south. It attains a maximum thickness of over 300 feet just west of the Alberta-Saskatchewan interprovincial boundary and is thinnest in the southeast corner of the map area where it is about 120 feet thick. Some of the local thickness anomalies which alter the regional isopach pattern can be attributed to solution of older Devonian salt beds during the time the sediments of the Seward Member were deposited.

To facilitate the description of the Seward Member the writer has divided it into a lower unit A and an upper unit B. Unit B in turn has a number of subunits B1, B2, and B3, in ascending order. Unit A includes the lower 60 to 140 feet of the Seward Member and is composed of a number of thin (about 5 to 7 feet thick) beds of greenish gray to light gray calcareous shales and light gray to light medium gray argillaceous limestones. These are interbedded with pale yellowish brown to moderate yellowish brown, microcrystalline to cryptocrystalline limestones, dolomitic limestones and dolomites and pale yellowish brown to dusky yellowish brown, microcrystalline to cryptocrystalline anhydrites. The carbonate rocks are commonly fossiliferous; generally the organic material is finely comminuted but the fossil remains which can be recognized include brachiopods, bryozoa, corals and large amounts of crinoid columnals. Pelletoidal or oolitic rocks are locally prominent. The spherites, which are ovoid to irregularly-shaped, range between 0.06 mm. and 1.6 mm. in

diameter. Rarely the spherites and fossil remains are intermixed. Across the central portion of the distribution area of the Seward Member from the 106th meridian of longitude as far west as the 109th meridian of longitude, the lithologies of unit A have a distinctly rhythmic pattern. A typical rhythm includes the following succession in descending order:

Marlstone or calcareous shale,

Anhydrite,

Argillaceous limestone or dolomite,

Fossiliferous fragmental limestone.

The rhythms have thicknesses ranging from 8 feet to 23 feet and generally number about 5 or 6 throughout the thickness of unit A. Most of the individual lithologic units are relatively thin (from less than a foot to about 10 feet). The rhythms are best observed in the Tidewater Parkbeg Crown No. 1 well (Lsd. 10-32-18-3W3) which was cored throughout the entire thickness of the Seward Member. In wells where only well cuttings are available from unit A it is extremely difficult to distinguish all of the individual lithologies, since some of the beds are too thin to be recognized in drill cuttings. In west-central Saskatchewan the argillaceous and non-argillaceous carbonates are fewer, but thicker. This is illustrated in Figure 15 by well numbers 10, 11, 12, 13, 14, 20, 21, 22 and 36. There are also less anhydrites in unit A in this region and they change facies toward the north where they grade laterally into carbonate rocks. Both the argillaceous and non-argillaceous carbonates are commonly fossiliferous. Most of the organic remains, however, are finely comminuted and with exception of the crinoid columnals are difficult to identify. Thin pelletoidal or oolitic beds are also present. Some of

the argillaceous strata include thin light gray to greenish gray shales interbedded with thin carbonates which illustrate pinch and swell structure common to this type of lithologic association. In north central Montana, the anhydrites found in unit A in western Saskatchewan are absent due to a change in facies and the argillaceous beds are both thinner and less numerous.

A sporomorph zone, present in the middle to lower portion of this unit, may be correlated over a broad area of western Saskatchewan. However, it is less persistent than the stratigraphically lower zones in the Duperow Formation and has been recognized in only a few wells in eastern Alberta.

The upper 90 to 140 feet of the Seward Member is included in unit B. This unit has three main lithologic divisions each of which has been set aside as a subunit by the author. Subunit B1 occupies the lower 25 to 100 feet of unit B. It has a wide lateral extent and underlies most of the area in which the Seward Member can be recognized. To the west the subunit thins and finally changes facies to a non-argillaceous carbonate a few miles west of the arbitrary cut-off established for the Fairholme and Saskatchewan Groups (Figures 2 and 15). The subunit also thins markedly in north central Montana, but can be identified as far south as the Duperow subcrop along the southern edge of the map area.

Subunit B1 consists of light gray and minor yellowish gray, very argillaceous, cryptocrystalline limestones and scattered dolomites. These are commonly thinly bedded and interbedded with light gray to greenish-gray calcareous shale. The shale-limestone association generally shows the effects of early post-depositional compaction by the presence of sedimentary boudinage structures. These strata are commonly

highly fossiliferous with brachiopods, ostracoes and crinoid columnals making up the bulk of the organic remains. Core taken from this unit at two widely separated localities (Tidewater Duperow Crown No. 1 Lst. 4-9-35-16 W3 and Tidewater Parkbeg Crown No. 1 (Lsd. 10-32-18 3W3) indicate that some of the sediments which now make up the strata of subunit B1 were reworked before lithification. Examples of these reworked beds are shown on Plate 6 Nos. 1 and 2 and their origin and significance is discussed in detail in the chapter concerning sedimentation (p.88). Doubtless if more cored intervals were available these reworked beds would be found to be more common not only in the argillaceous beds of subunit B1 but also in other argillaceous strata within the Duperow Formation. The author also observed thin beds of limestone pebbles in this subunit in the core from the Tidewater Duperow Crown No. 1 well. These pebble beds are similar to those reported from a stratigraphically lower horizon in the Duperow Formation. Four 1/2-inch to 1-inch thick beds were observed, each containing subangular to well-rounded, black, flat to irregularly-shaped pebbles ranging in size from a wuarter of an inch to 1 1/4-inches long. The sizes and shapes of these pebbles are somewhat different from those previously described and illustrated in Plate 5, but their origins are probably similar. Comminuted brachiopod remains and crinoid columnals are associated with these pebble beds.

The 30 to 75 feet of strata overlying subunit B1 are included in subunit B2. This subunit has much the same geographic distribution as subunit B1, but it does not change facies toward the west beyond the arbitrary cut-off. Instead it loses its identity as it becomes part of the Peechee Member of the Southesk Formation. Subunit B2 is thinnest where subunit B1 is thickest and thickens at the expense of the underly-

ing subunit. The rocks which make up subunit B2 are pale to moderate yellowish brown, and yellowish gray, microcrystalline to cryptocrystalline, highly dolomitic limestones and dolomites. Fossil remains are not common in this unit, but have been observed in a few wells. For the most part dolomitization has affected the organic material making it difficult to identify. Brachiopods seem to be the most common fossil found. Oolites or pseudo-oolites are also rare. The carbonate rocks of subunit B2 are interbedded with pale to dusky yellowish brown, microcrystalline to cryptocrystalline anhydrite, particularly in westernmost Saskatchewan and eastern Alberta (Figure 15). The anhydrites change facies to carbonate in the east and in the south. However, these carbonates are commonly affected by secondary anhydritization in the form of large blebs of white, translucent, cryptocrystalline anhydrite and porphyroblasts of dusky yellowish brown anhydrite crystals. Thin beds of greenish gray, calcareous shale and light gray to yellowish gray marlstone have been observed as interbeds with the carbonates of the eastern half of the map area.

The top of the Seward Member is marked by a thin, persistent shale or very argillaceous carbonate bed which has been called subunit B3 by the writer. Subunit B3 is rarely greater than 20 feet thick or less than 5 feet. It has a wide north-south and easterly lateral distribution, but is limited in the west by a change of facies to non-argillaceous carbonate or a merging with the lower argillaceous beds of the Grotto Member of the Southesk Formation (Figure 15). The writer established the position of the arbitrary cut-off between the Saskatchewan and Fairholme Group in the vicinity of this facies change or merging of subunit B3, because, where this occurs, the top of the Duperow Formation

is no longer recognizable and the formational subdivisions of the Saskatchewan Group are no longer significant. To the north subunit B3 is truncated by pre-Cretaceous erosion, but in the south the author has traced this bed beyond the southern limits of the map area as far as the north front of the Beartooth Mountains of southern Montana. There, in good exposures along the Boulder River Canyon, the upper 300 feet of the Jefferson Formation is characterized by a 45 foot thick, cliff-forming carbonate thought to be the Birdbear equivalent (Clements, 1957; McMannis, 1962). This is underlain by 15 feet of grayish yellowish orange to pale yellowish brown, microcrystalline, silty and argillaceous dolomite with stringers of grayish green calcareous shale in the upper few feet. These strata underlying the Birdbear equivalent are thought to be coeval with subunit B3.

Subunit B3 varies lithologically from vari-coloured shales to greenish and grayish shales to very argillaceous limestones. The eastern portion of the map area is primarily underlain by vari-coloured greenish gray to moderate reddish brown, calcareous shale or mudstone with minor silt occurrences. This rock type extends as far west as the Maple Creek area and as far north as the Elbow area (Figure 15). In north-central Montana it does not extend much beyond the vicinity of the international boundary. The vari-coloured shales grade laterally into greenish gray and grayish green, calcareous shales interbedded with thin beds of pale yellowish brown to olive gray, microcrystalline to cryptocrystalline, argillaceous limestone or dolomitic limestone. This rock type is particularly common beyond the northern and southern limits of the vari-coloured shales. A conglomeratic bed within subunit B3 was cored at one location in the region underlain by the shaly facies of this subunit.

This conglomeratic material consists of subangular to rounded limestone fragments between 0.68 mm. and 16 mm. in diameter, in a shaly matrix, and was observed in the Tidewater Birsay Crown No. 1 well (Lsd. 13-4-25-8W3).

The shales of subunit B3 change facies to light olive gray to medium light gray, microcrystalline to cryptocrystalline, very argillaceous limestones, dolomitic limestones and minor dolomites in both a northerly and westerly direction. In southwestern Saskatchewan thin pale yellowish brown to dusky yellowish brown, microcrystalline anhydrites are interbedded with the carbonates but rarely are the predominant rock type in the unit (Figure 9). Thin stringers or partings of shale are probably associated with the carbonates, but are difficult to distinguish in drill cuttings, but shaly material was found intermixed with a brecciated and highly disturbed sequence of rocks from core of this subunit taken from the Ceepee Riley Lake No. 3-4 well (Lsd. 3-4-39-13W3). In this core there are about 10 feet of rock which appear to have been subaqueously disturbed. Bedding is disrupted and contorted and subangular carbonate fragments are distributed throughout.

In the vicinity of the Fairholme Group-Saskatchewan Group arbitrary cut-off the carbonate bed at the base of the Birdbear Formation which is non-argillaceous over the eastern half of the map area changes facies to argillaceous carbonate with the result that it becomes difficult to distinguish subunit B3 from the overlying strata of the Birdbear Formation (Figure 15). West of this arbitrary cut-off the beds equivalent to the Seward Member belong to the Peechee Member of the Southesk Formation (Figures 3 to 6, inclusive). The Peechee Member consists mainly of pale yellowish brown to yellowish gray, microcrystalline

to cryptocrystalline dolomite and rare dolomitic limestone. Fossil material is sparse in these carbonates and is limited to a few widely dispersed brachiopod and ostracod specimens. Pale yellowish to dusky yellowish brown anhydrites are interbedded with the carbonates and are locally abundant. Thick concentrations of euhedral dolomite grains are commonly encountered in the wells penetrating the southern Alberta Marginal Reef Complex and are also found in thinner concentration for some distance east of the marginal reef (Figure 15).

BIRDBEAR FORMATION

The Birdbear Formation overlies the Seward Member of the Duperow Formation. The contact between these two stratigraphic units appears to be conformable, but the presence of red beds, breccia and conglomerate deposits in subunit B3 of the Seward Member may be interpreted as evidence for the existence of a disconformity at the top of the Duperow Formation over at least part of the map area. This contact is easily recognized throughout the region east and south of the Fairholme Group-Saskatchewan Group arbitrary cut-off, and is chosen on mechanical logs as the transition point between the highly argillaceous beds of subunit B3 of the Seward Member and the generally non-argillaceous basal strata of the Birdbear Formation.

The upper contact of the Birdbear Formation and the superjacent Torquay Formation is irregular and gradational (Figure 16). However, in Western Saskatchewan there are local areas where the basal two units of the Torquay Formation appear to be absent and unit 3 of that formation lies directly on the Birdbear Formation. A similar situation appears to exist in a large portion of eastern Alberta, with the exception of a few

local areas where thin red bed deposits lie directly on the Arcs Member of the Southesk Formation, the evaporite and carbonate strata of the Wabamun Group directly overlie the Arcs Member (Belyea, 1955, p. 25). The author is of the opinion that these conditions indicate that a disconformity is locally developed between the Birdbear or its equivalents and the overlying formations. Sandberg and Hammond (1958, p. 2320) and Christopher (1961, Plate 2) also noted the presence of local disconformities at the top of the Birdbear Formation. Where the contact between the Birdbear and Torquay Formation is gradational, the basal beds of the overlying formation are commonly reddish and contain corroded dolomite and anhydrite fragments. There is a strong concentration of these fragments near the top of unit 2 of the Torquay Formation. Christopher (1961) interpreted the concentration of rock fragments at the top of this unit as evidence to the presence of a regolith, and therefore, to the presence of an unconformity. In the opinion of the writer the gradational and irregular nature of the upper contact of the Birdbear Formation, results from contemporaneous weathering of the rocks underlying the exposed surface now represented by the intraformational unconformity near the top of unit 2. The irregularity of the contact probably indicates variations in the depth of weathering. The regional significance of this intraformational unconformity is considered in later sections.

Lower Member The lower member of the Birdbear Formation occupies the lower 15 to 110 feet of that formation directly overlying the Seward Member of the Duperow Formation. The upper contact of the member has been located where there is a distinct lithologic change from the argillaceous beds of the upper part of the lower member to the poorly argillaceous basal strata of the upper member.

Within the study area the lower member is confined to western Saskatchewan and northernmost Montana. Its northerly extent is limited due to pre-Cretaceous erosion (Figure 2). In the west the member becomes unrecognizable beyond the Fairholme Group - Saskatchewan Group arbitrary cut-off as it and subunit B3 of the underlying Seward Member combine to form the unit which the writer for the purpose of reference has called the upper Ireton beds. They are the argillaceous strata in the Grotto Member of the Southesk Formation. To the south the lower member again loses its identity where the upper argillaceous beds change facies to non-argillaceous carbonates. In the east the lower member can be traced beyond the limits of the present map area, but cannot be recognized in southeastern Saskatchewan due to the change in facies mentioned above.

In southwestern Saskatchewan and northernmost Montana there is a broad area over which the lower member has a relatively uniform thickness averaging about 22 feet. Although, there is a local thickness anomaly in the southeast corner of western Saskatchewan where it reaches about 60 feet, the general regional thickening is to the west and north (Figure 17). The isopach map of this member (Figure 17) indicates that the axis of maximum regional thickness trends east-west through the Kindersley-Rosetown area of Saskatchewan. In this region the member ranges between 90 and 110 feet thick, but thins again north of this area. The map illustrates that there are local thickness anomalies superimposed on the regional trends, but these rarely exceed 60 feet. The upper Ireton beds show the same general regional thickening as the lower member, attaining their maximum thickness of 90 feet some 45 miles east of Stettler, Alberta. In the vicinity of the southern Alberta Marginal Reef

Complex the regional thickness trends of the upper Ireton beds are aligned with the reef complex. The thicknesses vary somewhat in this region, probably due to differential compaction of the upper Ireton beds over highs on the top of the marginal reef complex.

The lower member of the Birdbear Formation is primarily composed of carbonate rocks. The basal 8 to 18 feet consist of pale to moderate yellowish brown and yellowish to olive gray, microcrystalline to cryptocrystalline, limestones, dolomitic limestones and dolomites. These strata are commonly fossiliferous with brachiopods the most abundant fossil. Laminated beds of carbonate and carbonaceous shale partings are also common. Locally, in the eastern part of western Saskatchewan the carbonates become slightly argillaceous, but for the most part they do not lose their non-argillaceous aspect except in the vicinity of the Fairholme Group-Saskatchewan Group arbitrary cut-off. At this locality the basal beds of the lower member are light gray to olive gray, argillaceous, cryptocrystalline, limestones, dolomitic limestones or dolomites, which cannot be distinguished from the overlying argillaceous part of the lower member.

The upper 5 to 90 feet of the lower member of the Birdbear Formation are argillaceous, varying from slightly so in the southern and eastern parts of the map area to highly argillaceous in the west and north. In southern Saskatchewan these strata are relatively thin, but in the vicinity of the South Saskatchewan River (Figure 17) where there is a marked thickening of the lower member of the Birdbear Formation, the argillaceous beds thicken to become the dominant lithology in the member. In southern Saskatchewan and northernmost Montana these upper beds of the lower member consist of pale to moderate yellow-

ish brown and yellowish gray, microcrystalline to cryptocrystalline, slightly argillaceous limestones, dolomitic limestones and dolomites. Fossils are common either as comminuted unidentifiable remains or as well-preserved specimens, mainly brachiopods and ostracods. Some of the more argillaceous layers within these strata show the effects of early post-depositional compaction in the form of sedimentary boudinage. In the region north of the South Saskatchewan River where the argillaceous beds of the lower member thicken, there is a greater variety of rock types. The dominant lithologies are moderate to light olive gray and yellowish gray, microcrystalline to cryptocrystalline, very argillaceous limestones; pale yellowish brown to olive gray, microcrystalline to cryptocrystalline, argillaceous to very argillaceous dolomites; olive gray to light gray and greenish gray very calcareous shales; and light gray marlstones. Some of the limestones are thinly-bedded and interbedded with greenish gray and grayish green, calcareous, shales. Pinch and swell structures are commonly associated with these lithologies. Along the eastern side of the map area just south of Saskatoon (Figure 15) the upper strata of the lower member are silty rocks, varying in composition from light gray to yellowish gray, cryptocrystalline silty limestones to light gray, very calcareous siltstones containing well-sorted quartz grains in a marly matrix. The siltstones are commonly interbedded with greenish gray, highly calcareous shales. Locally the base of these argillaceous beds may contain a conglomeratic breccia similar to that observed in the Tidewater Birsay Crown No. 1 well (Lsd. 13-4-25-8W3). In this well the breccia which is about 17 feet thick, consists of olive gray, thinly-laminated, subangular to rounded dolomite clasts between 0.23 mm. and 25.0 mm. in diameter, in a moderate reddish brown clayey matrix. It is

difficult to reach a conclusion concerning the origin of this conglomeratic breccia. The 6 feet of beds overlying it contain angular to subangular carbonate fragments and much of the rock including the conglomeratic breccia has high angle, slickensided fractures. However, the author feels that the conglomeratic breccia probably originated as an aqueous deposit and the overlying beds may represent a solution-collapse breccia or possibly a talus breccia. Further consideration is given these rocks in the section concerned with sedimentation. The layers near the top of the argillaceous portion of the lower member in the Tidewater Birsay Crown No. 1 well are also somewhat different from those found at most other locations. In this well the uppermost 15 feet consists of moderate yellowish brown, cryptocrystalline to microcrystalline, in part laminated, dolomites and dolomitic limestones, interbedded with a half of a foot to 4 foot thick beds of fissile, dusky yellowish brown carbonaceous shale. Sedimentary boudinage is common in some of the thinly-bedded portions of the succession. Pyrite is widely disseminated through the carbonates, which contain brachiopods, gastropods, ostracods and brachiopod spines. The carbonaceous shale beds also contain a sparse fauna made up of lingulid brachiopods, tentaculitids, conodonts, scolecodonts and sporomorphs. Another lithology which probably occurs only locally was observed in drill cores from this horizon, this being the flat pebble conglomerates similar to those described from other argillaceous zones lower in the section. Toward the west and northwest the argillaceous portion of the lower member of the Birdbear Formation becomes part of the upper Ireton beds which appear to be more dolomitic than the equivalent strata to the east. The upper Ireton beds are dolomitic to the edge of the southern Alberta Marginal Reef Complex where they pass laterally into the shales and argil-

laceous limestones of the Ireton Formation.

Over much of western Saskatchewan the upper beds of the lower member of the Birdbear Formation contain abundant fossil remains. The specimens are generally well preserved in the shaly strata and highly comminuted in the carbonate layers. The biota includes brachiopods, corals, bryozoa, gastropods, ostracods, tentaculitids, crinoid columnals, algal nodules and sporomorphs. The sporomorphs are commonly in a 10 to 15 foot zone at the top of the lower member, but as the zone is traced to the west it rises slightly and is present in the lower few feet of the upper member. This zone may be recognized as far west as the southern Alberta Marginal Reef Complex.

Upper Member The upper member of the Birdbear Formation includes the 20 to 140 feet of essentially non-argillaceous carbonates overlying the lower member and subjacent to the Torquay Formation of the Three Forks Group. The contact with the lower member, where that member is recognizable, is gradational in the region where the thick argillaceous beds of the lower member are present, and well-defined where the underlying beds become less argillaceous. The upper contact is coincident with the top of the Birdbear Formation.

Most of the region of study is underlain by the upper member or its lateral equivalents. Its northern extent is limited due to removal during a period of post-Mississippian to pre-Cretaceous erosion (Figure 2). In the southeast the lower contact of this member becomes unrecognizable because of a change of facies in the underlying strata. South of the region where this facies change occurs, the total Birdbear Formation is truncated by an erosional surface developed in early Mississippian times (Figure 2). The upper member can be identified without

difficulty throughout the western part of north central Montana. To the east the upper member is identifiable beyond the limits of the map area, but the contact with the lower member is not easily distinguished where that member undergoes a change of facies. In the west the upper member may be recognized west of the Fairholme Group-Saskatchewan Group arbitrary cut-off and as far as the southern Alberta Marginal Reef Complex where it becomes part of the Woodbend Group-Winterburn Group succession.

There is little indication of the development of trends in the variations of regional thickness on the isopach map of the upper member. Throughout most of the area of study the thicknesses appear to vary randomly. The maxima range between 80 and 140 feet and the minima are between 35 and 50 feet. However, the member does thin regionally to the south where it is about 20 feet thick or less in western Montana. It attains a maximum thickness of 139 feet in the region north of Maple Creek in western Saskatchewan. The variation in thickness of this unit is probably a reflection of the irregular nature of the upper contact of the Birdbear Formation. It was previously suggested that this irregularity of the upper contact results from the different depths to which post-Birdbear weathering extended. Therefore, in the case of the upper member the minimum thicknesses probably represent areas where weathering extended to a greater depth than in the areas of maximum thickness. In the vicinity of the southern Alberta Marginal Reef Complex the thickness of the lateral equivalent of the upper member varies locally, probably due to draping of the sediments of this member and the underlying beds over isolated highs on the top of the reef complex.

Yellowish gray to moderate olive gray and pale yellowish brown, microcrystalline to cryptocrystalline dolomite is the dominant carbonate

lithology in the upper member of the Birdbear Formation (Figure 15). Limestones and dolomitic limestones having the same general colours and textures are confined to widely dispersed localities throughout the area of study. In the Kindersley-Rosetown area of west central Saskatchewan the dolomites are primarily the rhombic type similar to that type found in the Wymark Member of the Duperow Formation (pages 32 and 33). This lithologic type was observed in a number of wells in the region outlined and attains a maximum thickness of 80 feet. A similar lithology was observed at other scattered locations within the study area. Other locally developed rock types of some importance include the laminated beds of carbonate and carbonaceous shale, also described elsewhere (page 34), and pelletoidal or oolitic accumulations containing ovoid to irregularly-shaped spherites, 0.15 mm. to 0.5 mm. in diameter. In some instances the carbonaceous shale and carbonates become thicker than "laminae" and in these examples they very often illustrate pinch and swell phenomena.

The carbonates of the upper member are generally non-argillaceous throughout most of the area of study. However, there are locally developed slightly argillaceous beds and thin shale partings in various locations in western Saskatchewan and the basal part of this member where it lies on the highly argillaceous beds of the underlying member increases in argillaceous content downward. In an area straddling the Alberta-Saskatchewan interprovincial boundary just northwest of Kindersley, Saskatchewan (and outlined by a red line in Figure 18) the upper beds of this member are fairly argillaceous and contain thick interbeds of olive gray to light gray, massive, calcareous mudstone. In this region the lower 60 feet of this member consists of non-argillaceous

carbonate and the remainder contains the argillaceous carbonates and shaly beds.

South of the above mentioned region in westernmost Saskatchewan, the beds which are in part laterally equivalent to the argillaceous interval of the upper part of the upper member include pale yellowish to dusky yellowish brown, microcrystalline to cryptocrystalline anhydrite interbedded with non-argillaceous carbonates (Figure 15). This area is the most extensive region of evaporite concentration in the upper member, but other local deposits were also found. There is another area of abundant evaporite beds in the upper part of strata which are in part equivalent to the Birdbear Formation, in the vicinity of the southern Alberta Marginal Reef Complex. These evaporites and the interbedded rocks were placed into the Crowfoot Formation by Belyea and McLaren (1957), but as they are traced to the northwest they are thought to be the lateral equivalent of part of the Nisku Formation (Figure 6).

In the southeastern part of the area of study where the Birdbear Formation can not be divided into members due to a change of facies in the lower beds, the formation is commonly quite dolomitic and sparse in fossil remains except for the lower 20 feet which is probably coeval with the lower member and which is generally quite fossiliferous (Figure 15).

Fossils are not abundant throughout the areal extent of the upper member in the study area, but may be locally abundant. The biota includes, brachiopods, bryozoa, corals, ostracods, stromatoporoids and algal nodules and encrustations. The basal strata west of the Alberta-Saskatchewan interprovincial boundary also contain sporomorphs.

THREE FORKS GROUP

Torquay Formation - Units 1 and 2 It is necessary to include a description of units 1 and 2 of the Torquay Formation, as defined by Christopher (1961) because of the close relationship between these beds and the underlying Birdbear Formation.

Units 1 and 2 underlie most of southern Saskatchewan, but are truncated to the north by the extensive pre-Cretaceous erosional surface. In an area northwest of Kindersley the units become difficult to recognize due to a change in the lithologic character of the basal strata of the Three Forks Group. In eastern Alberta there is a broad area where 1 and 2 are absent due to either non-deposition or erosion during a static period following Birdbear sedimentation and prior to the deposition of either the sediments of the Stettler Formation or those of the Three Forks Formation. Large areas in the southwestern part of the map area were probably similarly affected by the static period, since units 1 and 2 cannot always be recognized in this region. On the northwest side of the area where these units are absent (in eastern Alberta) there is a thick sequence of anhydrites, carbonates and red bed deposits making up the Crowfoot Formation (Figure 16). The lower part of this formation has been shown to be equivalent to part of the upper member of the Birdbear Formation. The upper anhydrites and red beds are probably equivalent to units 1 and 2 of the Torquay Formation (Figures 3 and 4). These units can be identified for a considerable distance east of the present map area (Christopher, 1961).

The combined thickness of units 1 and 2 varies widely between 103 and 14 feet. Locally the combined units may be thick where the under-

lying Birdbear Formation is thin and vice versa, but in some localities (see well No. 13, Figure 16) the units are thick over a relatively thick Birdbear Formation.

According to Christopher (1961) unit 1 usually includes two rock types, the basal part is a slightly weathered to unweathered, tan, finely crystalline granular dolomite, generally interbedded with thin greenish gray to grayish green, calcareous shales. This is persistent over much of western Saskatchewan and probably represents a transition between the non-argillaceous beds of the Birdbear and the argillaceous overlying strata. These basal transitional beds are commonly subjacent to a grayish green dolomitic mudstone or shale with minor weathered dolomite and anhydrite fragments. Unit 2 consists of a dolomitic mudstone with concentrations of rotted yellowish gray, microcrystalline to cryptocrystalline dolomite fragments and white, fibrous, anhydrite fragments. Christopher (1961) considered this concentration of dolomite and anhydrite fragments to represent a regolith. In the region northwest of Kindersley, where the underlying uppermost strata of the Birdbear Formation are argillaceous, these basal beds of the Three Forks Group are composed of a sequence of yellowish green to grayish green, waxy, calcareous shales and mudstones interbedded with yellowish gray, microcrystalline, argillaceous limestones. Farther north these argillaceous strata grade laterally into anhydrites of the Stettler Formation of Kents (1959). This change in lithologic character of the basal beds is well illustrated in the core from the Ceepee Dukesbury 13-18 well (Lsd. 13-18-34-21W3). The significance of this change of facies is considered in the chapter concerned with geological history (p. 140).

PALAEONTOLOGY, CORRELATION AND AGE

General Character of the Fauna

The fauna collected during this study was relatively poor. Brachiopods were most abundant and 15 genera were identified. Other forms included 6 genera of stromatoporoids, 1 genus of charophytes, 1 genus of branchiopod, 1 genus of gastropod and a variety of unidentified algae and bryozoa. The author also collected a number of well-preserved specimens of tetracorals, which were sent for identification to Dr. A. E. H. Pedder of the Geological Survey of Canada. Unfortunately these identifications are not available at this time. A quantitatively-poor microfauna was also collected, including the sporomorphs _Tasmanites_ and _Leiosphaeridia_, numerous unidentified ostracods and occasional conodonts and scolecodonts.

The best preserved macrofaunal specimens were obtained from shaly beds. Fossils collected from non-argillaceous carbonate rocks were seldom well preserved and usually were either unidentifiable or identifiable as to genus only.

Stratigraphic Distribution of the Fauna

DUPEROW FORMATION

Elstow and Saskatoon Members

Anostylostroma sp.

Stictostroma sp.

? _Syringostroma confertum_ (Stearn)

Trupetostroma cf. _T. papillatum_ Stearn

? _Trupetostroma_ sp.

Atrypa albertensis Warren

Atrypa cf. *A. independensis* Webster

Atrypa cf. *A. montanensis* Kindle

Atrypa multicostellata Kottlowski

Atrypa sp.

Eleutherokomma jasperensis (Warren)

Eleutherokomma cf. *E. jasperensis* (Warren)

Eleutherokomma killeri Crickmay

Eleutherokomma cf. *E. leducensis* Crickmay

Eleutherokomma reidfordi Crickmay

Eleutherokomma cf. *E. reidfordi* Crickmay

Ostracods

Trochiliscus devonicus (Wieland)

Trochiliscus regulatus Peck

Trochiliscus septemcostatus Peck

Leiosphaeridia sp.

Tasmanites sp.

Most of the brachiopods are from the Elstow Member with the exception of *A.* cf. *A. independensis*, *A. multicostellata* and *E.* cf. *E. leducensis* which were collected from the Saskatoon Member. The stromatoporoid fauna was collected entirely from the Saskatoon Member.

A. albertensis has been reported from the *Pugnoides kakwaensis* zone of the Flume Formation of the Jasper, Alberta area (McLaren, 1954; Patterson, 1955), and from the Waterways (Beaverhill Lake) Formation of northeastern Alberta (Warren and Stelck, 1956). A variety of this species was collected also from the *Spirifer strigosus* and *Macgeea*

proteus zones of the Hay River Formation (Warren and Stelck, 1950). In the Alberta Rocky Mountains Atrypa independensis has been recorded from the Flume (restricted) Formation (McLaren, 1954; Taylor, 1957) and from the Hollebeke Formation (Price, 1965). It has also been found in the Waterways (Beaverhill Lake) Formation in northeastern Alberta (Warren and Stelck, 1956). In Saskatchewan Powley (1951) obtained Atrypa cf. A. independensis from the M-5 Formation (straddling the contact between the Wymark and Seward Members of Kent, 1963) of his Moose Jaw Group and from unit 12 (part of the Souris River Formation) of his Duperow Formation. The writer has collected A. independensis from the Seward and Wymark Members as well as from the Elstow and Saskatoon Members. Atrypa cf. A. montanensis was first recorded as Atrypa spinosa var. montanensis in the Jefferson Formation of Montana (Kindle, 1908). This species was later illustrated by Merriam (1940) and called Atrypa cf. A. montanensis. Laird (1947) noted the occurrence of this species in unit Db of the Jefferson Formation (the lower $\pm$ 200 feet of Sandberg's 1965 lower member), but Norris (1955) suggests that Laird's specimens are too coarsely costate to be Atrypa cf. A. montanensis. Wilson (1955) found this species in both his upper and lower Duperow units in the Jefferson Formation. This species has also been recorded from the Mount Hawk Formation in the Alberta Rocky Mountains (Norris, 1955). Kottlowski (1950) examined numerous specimens of Atrypa from the Jefferson Formation of Montana among them was the species Atrypa missourensis obtained from unit Db by Laird (1947), which Kottlowski considered to belong to a new species, Atrypa multicostellata. In the Alberta Rocky Mountains this species has been found in the basal beds of the Cairn Formation of the Jasper, Alberta area (Mountjoy, 1965); from the Maligne and Flume Formations of the Rocky

Mountains north of Banff, Alberta (McLaren, 1955; Mountjoy, 1965; Norris, 1955), and in the Hollebeke Formation of the Flathead Area, Alberta and British Columbia (Price, 1964, 1965). In the subsurface of Alberta *Atrypa multicostellata* occurs in the upper part of the Cooking Lake Formation (Belyea and McLaren, 1956).

Eleutherokomma jasperensis generally occurs in the Maligne and Flume Formations of the Alberta Rocky Mountains (McLaren, 1955; Taylor, 1957; Mountjoy, 1965) but has been found also in the Perdrix Formation (McLaren, 1955). Price (1965) obtained specimens of this species from the upper member of the Hollebeke Formation of the Flathead Area, and Laird (1947) reported it from unit Db of the Jefferson Formation of Montana. Belyea (1955) observed specimens of *E. jasperensis* in the upper part of the Cooking Lake Formation, the overlying Duvernay Formation and in the transitional beds which overlie the latter formation. The vertical range of *E. killeri* and *E. leducensis* is similar to that of *E. jasperensis*. In the Rocky Mountains these species have been reported only from the Maligne Formation (McLaren, 1954; Taylor, 1957), and in the subsurface they have been obtained from the upper beds of the Beaverhill Lake Formation through to the transitional beds between the Ireton and Duvernay Formation (McLaren, 1954; Belyea, 1955; Belyea and McLaren, 1956; Warren and Stelck, 1956; Taylor, 1957; Crickmay, 1957). Powley (1951) recorded *E. leducensis* from the M-5 Formation of his Moose Jaw Group. Crickmay (1950) suggested that *E. reidfordi* attained a higher state of evolution than all of the other above-mentioned species of *Eleutherokomma*, and, although it overlaps the ranges of the other species to a slight degree, its range extends somewhat higher stratigraphically. In the outcrop areas *E. reidfordi* has been recorded from the lower part

of the Hay River Formation of northern Alberta (Pedder, 1960; Belyea and McLaren, 1962), from the Maligne Formation of the Jasper area, Alberta (Mountjoy, 1965) and from the upper member of the Hollebeke Formation of the Flathead area (Price, 1964; 1965). Warren and Stelck (1950) and Crickmay (1950) report the occurrence of this species in the Ireton Formation in the subsurface of central Alberta.

The regional stratigraphic significance of the stromatoporoid fauna of the Duperow Formation is difficult to determine since each region of western Canada seems to be dominated by a distinctive local group associated with a few species which have a wider lateral range (Stearn, 1966). Two of the more widespread species are: ? *Syringostroma confertum* reported from the Beaverhill Lake, Leduc and Mikkwa Formations (Stearn, 1966) and *Actinostroma clathratum* observed in the Hay River, Twin Falls, Cooking Lake and Leduc Formations (Klovan, 1966; Stearn, 1966).

To the writer's knowledge the three species of trochiliskid charophytes have not been previously reported in western Canada, as virtually no work has been carried out for publication on these organisms in this region. A full discussion of the stratigraphic significance of the sporomorphs *Tasmanites* and *Leiosphaeridia* is included in a separate section.

Wymark Member

Actinostroma cf. *A. clathratum* Nicholson

? *Anostylostroma* sp.

? *Ferestromatopora* sp.

? *Syringostroma confertum* (Stearn)

? *Trupetostroma* sp.

Atrypa cf. *A. albertensis* Warren

Atrypa clarkei Warren

Atrypa cf. *A. independensis* Webster

Atrypa multicostellata Kottlowski

Atrypa sp.

Eleutherokomma reidfordi Crickmay

Schizophoria sp.

Theodossia sp.

Rhabdostichus cf. *R. pulex* (Clarke)

Ostracods

Tasmanites sp.

Leiosphaeridia sp.

Most of the elements of this fauna are similar to the fauna of the Elstow and Saskatoon Members. The *E. reidfordi* was obtained from the basal beds of the Wymark Member, but some of the other forms were found in the middle and upper units of this member, e.g. *Atrypa* cf. A. *albertensis*, *Atrypa* cf. *A. independensis* and *A. multicostellata*. *Atrypa* cf. *A. albertensis* is probably similar to a variety of this species recorded from the Hay River Formation (Warren and Stelck, 1950). *Atrypa* cf. *A. independensis* may be similar to the subspecies *A. independensis mclareni* which Norris (1955) found in the lower part of the Mount Hawk Formation. The presence of *A. multicostellata* above the occurrence of *E. reidfordi* appears to be somewhat higher, stratigraphically, than it has previously been found, which may indicate that this species has a broad vertical range. Warren (1944) described *A. clarkei* from the Waterways (Beaverhill Lake) Formation. The presence of this species in the middle unit of the Wymark Member, and therefore, above the highest reported occurrence of *E. reidfordi* in western Saskatchewan may

indicate that this specimen may be one of the subspecies proposed by Norris (1955), e.g. A. clarkei clearwaterensis or A. clarkei idlewildensis, which are found throughout the Mount Hawk Formation of the Alberta Rocky Mountains. Wilson (1955) observed A. clarkei in both the basal and topmost beds of the lower Duperow unit (unit Db of Sloss and Laird, 1947) of the Jefferson Formation.

In the area of study Rhabdostichus cf. R. pulex was found in the middle and upper units of the Wymark Member. Wilson (1956) reported the range of this species to be from the uppermost beds of the Souris River Formation to the lowermost strata of his upper Duperow unit (a unit which includes part of the middle unit and part of the upper unit of the Wymark Member and all of the Seward Member of Kent, 1963), but according to him they are most abundant in the lower part of the Duperow Formation. Rhabdostichus cf. R. pulex occurs also in unit Db of the Jefferson Formation of the Montana surface exposures (Wilson, 1955, 1956) and in the lower 50 feet of the Duperow Formation in the standard subsurface reference section of the upper Devonian in the Mobil Oil Producing Co. No. 1 Birdbear well (C SE¼-22-149N-91W) Dunn Co., North Dakota (Sandberg and Hammond, 1958). In northern Alberta Loranger (1965) recorded Rhabdostichus cf. R. pulex from the top of the Cooking Lake Formation. According to Loranger (1965) this occurrence marks the upper limit of the vertical range of this species in northeastern Alberta.

Seward Member

Atrypa bentonensis Stainbrook

Atrypa hackberryensis Fenton and Fenton

Atrypa cf. A. hackberryensis Fenton and Fenton

Atrypa cf. A. independensis Webster

Atrypa scutiformis Stainbrook

Atrypa spp.

Ambocoelia? sp.

Nervostrophia maclareni Pedder

Productella? sp.

Stropheodonta iowaensis Owen

Tenticospirifer? sp.

Theodossia? sp.

Tasmanites sp.

Leiosphaeridia sp.

The fauna of the Seward Member of the Duperow Formation is significantly different from those of the underlying members. Atrypa bentonensis occurs in the Mount Hawk Formation of the Alberta Rocky Mountain region and in the Spirifer strigosus zone of the Grumbler Group in the Hay River area of northern Alberta (Warren and Stelck, 1956). A. hackberryensis was reported from the Macgeea proteus zone in the Escarpment Member of the Hay River Formation, from the Spirifer strigosus zone of the Grumbler Group and from the Tenticospirifer cyrtiniformis zone of the Mount Hawk Formation (Warren and Stelck, 1956). A. scutiformis was found in the Waterways (Beaverhill Lake) Formation of northeastern Alberta (Warren and Stelck, 1956). Its occurrence in the Seward Member indicates that this species has a wide vertical range. Pedder (1960) obtained Nervostrophia maclerni from the Macgeea proteus zone in the Escarpment Member of the Hay River Formation. Another Waterways Formation fossil which seems to have an extended vertical range is Stropheodonta iowaensis (Warren and Stelck, 1956).

BIRDBEAR FORMATION

Atrypa cf. *A. hackberryensis* Fenton and Fenton

Atrypa cf. *A. iowaensis* Webster

Atrypa spp.

Cyrtospirifer spp.

Cyrtina sp.

Douvillinaria spp.

Gurichella sp.

Lingula sp.

Nervostrophia sp.

Productella sp.

Stropheodonta iowaensis Owen

Stropheodonta cf. *S. subdemissa* Hall

Tenticospirifer cyrtiniformis (Hall and Whitfield)

Platyceras sp.

Ostracods

Tentaculitids

Tasmanites sp.

Leiosphaeridia sp.

Many of the elements of this fauna were also found in the fauna from the underlying Seward Member of the Duperow Formation. *Atrypa* cf. *A. iowaensis* previously was recorded from the Waterways Formation and therefore like *A. scutiformis* and *S. iowaensis* would appear to have a broader vertical range than originally thought. Stropheodonta cf. *S. subdemissa* was found in the *Spirifer strigosus* zone of the Grumbler Group in the Hay River area (Warren and Stelck, 1956). The most significant fossil of

this fauna is Tenticospirifer cyrtiniformis an index fossil of the Upper Devonian in western Canada. T. cyrtiniformis occurs in the Calvinaria albertensis zone of the Mount Hawk Formation in the Alberta Rocky Mountains. Belyea (1955) obtained T. cyrtiniformis in the upper part of the Ireton Formation in the subsurface of central Alberta.

Sporomorphs

HISTORY OF THE GENERIC NOMENCLATURE OF TASMANITES AND LEIOSPHAERIDIA

The sporomorphs Tasmanites and Leiosphaeridia are disc-shaped or globular spore-like microfossils of uncertain affinities. The name Tasmanites was first proposed for them by Newton (1875, p. 341) when he described specimens from the "Tasmanite" and Australian "White Coal" in Tasmania. He encountered only one species which he called Tasmanites punctatus. About the same time that Newton described Tasmanites, Dawson (1871) described some sporomorph specimens from the Devonian black shale at Kettle Point on Lake Huron and called them Sporangites huronensis. Dawson had originally proposed the generic name Sporangites in an earlier paper published in 1863. In 1884 Dawson published descriptions of some other spore-like specimens sent to him by O. A. Derby from the Rio Trombetus and Rio Curua areas of Brazil. He called these specimens Protosalvinia braziliensis and eventually included some previously described Sporangites from the Rio Tapajos area of Brazil with Protosalvinia. Eisenack (1938) described forms similar to Dawson's Sporangites huronensis and called them Leiosphaera on the presumption that these forms pertained to the animal kingdom. In 1944 Schopf et al. in a summary of the literature on fossil spores rejected Dawson's (1863) genus Sporangites on the grounds that it was ambiguous and includes more than

one genus. They further proposed that those specimens without haptotypic features be removed from *Sporangites* and Dawson's (1884) *Protosalvinia* and be termed *Tasmanites*. They recommended that *Tasmanites punctatus* Newton be established as the type species.

Sommer (1956a) who had access to the topotype material from Derby's localities and from the Rio Tapajos area, agreed with Schopf *et al*. (1944) noting that Dawson had found sporomorphs of the unicentric type belonging to *Tasmanites* Newton (1875) emend. Schopf *et al*. (1944) in the material from the Rio Tapajos and *Protosalvinia braziliensis* Dawson emend. Krausel in the Rio Trombetus and Rio Curua material. Dawson, however, had placed the specimens all in the same genus and species namely *Protosalvinia braziliensis*. Sommer felt that a mistake of this nature was not justified since the specimens from the Rio Trombetus and Rio Curua material had haptotypic structures and could not be mistaken for *Tasmanites*. In the same paper he classified *Tasmanites* as "*Algae incertae sedis*" belonging to the Family *Tasmanaceae* Sommer, new family.

In 1958 Eisenack divided his sporomorph genus *Leiosphaera* into two. Forms having radial pores he considered as belonging to the genus *Tasmanites* and those without pores the genus *Leiosphaeridia*, new genus. He proposed the type species of this new genus as *Leiosphaeridia baltica* Eisenack 1958 and included both *Tasmanites* and *Leiosphaeridia* in the Family *Leiosphaeridae* Eisenack 1954 belonging to the Class Hystricosphaeridea. Timofiev (1956, 1959) proposed the generic name *Leiosphaeridium* as an alternative to *Leiosphaera* Eisenack 1938, but Downie and Sarjeant (1963) rejected this term as they believed it to be a junior synonym of *Tasmanites*.

Downie, Evitt and Sarjeant (1963) proposed a reclassification

of palaeomicroplankton. One of their suggestions was that all genera of uncertain affinity, previously classed as hystrichospheres be placed into a group "_incertae sedis_" which they called Acritarcha. Within the Acritarcha they established "morphological Subgroups and Infragroups without designated types". They were of the opinion that a subdivision of this manner would facilitate future reclassification of the various subgroup and infragroup forms when more became known about their origins. Among the palaeomicroplankton classified in this way was _Leiosphaeridia_ Eisenack 1958 which was included in the subgroup Sphaeromorphitae. In the case of _Tasmanites_, however, they were of the opinion that conclusive evidence had been presented in the literature indicating that _Tasmanites_ Newton 1875 in association with other similar forms (_Crassosphaera_ Cookson and Manum 1960, _Pleurozonaria_ O. Wetzel, 1933, _Tytthodiscus_ Norem 1955 and _Zonosphaeridium_ Timofiev 1956) were referable to the Chlorophyceae and attributed all five genera to the Family _Tasmanaceae_ Sommer 1956.

GENERIC CHARACTERISTICS

Schopf _et al_. (1944) outlined the generic characteristics of the genus _Tasmanites_ and these are quoted in part below:

"Symmetry - Unicentric; there is evidently a center and not an axis of symmetry as in spores of bonafide plants.

Shape - Originally spherical; except where protected compression has altered them into disks with a few sporadic rounded folds.

Size - Ranging from less than 100 microns to 600 microns[1]

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[1] (Author's footnote) Sommer (1953, 1956a, 1956b) has described 10 species with size ranges from a minimum of 100 to 175 microns in diameter for _Tasmanites moseai_ Sommer to a maximum of 370 to 710 microns in diameter for _Tasmanites avelinoi_ Sommer.

or slightly greater diameters. Forms greatly in excess or much smaller than these diameters are suspect because they vary so greatly from the genotype species.

Ornamentation - Surface smooth and glistening in reflected light at low magnification; more detailed examination shows more or less rugosity which may be in part attributable to preservation. More or less regularly spaced punctae varying in number on different forms are visible, but not conspicuous. The forms may be described as essentially lacking in external ornamentation.

Haptotypic features - Entirely absent. False conclusionshave been drawn either from different forms in association with Tasmanites or from specimens poorly preserved and misinterpreted. Absence of trilete satures is diagnostic.

Wall - Generally moderately thick, mostly 1/10 to 1/25 of the diameter; wall evenly developed on all surfaces and never membranous, often punctate[1] with pores tapering from very small orifice on the outside; sometimes the punctae are very sparse, in other species they may be so densely packed as to give a radially striate appearance. Poorly defined concentric bands may be present in the wall, but these are ordinarily not easily visible unless material is sectioned. In optical section (transmitted light) aside from punctae, walls generally appear homogeneous.

Eisenack (1958) defined Leiosphaeridia as thin-walled, hollow and spherical organic remains. They consist of a very resistant light

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[1] (Author's footnote) According to Eisenack (1958) in its youthful stage Tasmanites is always thin walled and without pores and consequently not easily distinguished from Leiosphaeridia.

yellowish to dark red brown transparent, organic substance. Like Tasmanites they are often found in the form of compressed or irregularly folded discs. In contrast to Tasmanites, pores are absent even in the adult stage and a pylome is common.

ORIGIN

The origin of Tasmanites and Leiosphaeridia has been a matter of considerable controversy. Newton (1875, p. 350) suggested that Tasmanites might have been spores or sporangia of some lycopodiaceous plant and was strongly convinced of their vegetative origin. Dawson (1884) also considered them to be spores. Schopf et al. (1944) concluded that the absence of nitrogen in the chemical composition of Tasmanites eliminated the animal kingdom as a possible origin, but since then Schopf (1957, p.712) indicates that the absence of nitrogen is not conclusive evidence against animal affinities. If, however, Tasmanites does belong to the plant kingdom the absence of evidence of a tetradic nature suggests a possible algal origin (Schopf et al. 1944). Sommer (1956a) was of the opinion that Tasmanites shows algal affinities; he felt that they were independent organisms, and unlike spores in this respect which are, in fact, specialized reproductive bodies. In a recent paper (Wall, 1962), Tasmanites and Leiosphaeridia were compared to two recent phytoplanktonic organisms, Pachysphaera pelagica Ostenfeld and Halosphaera minor Ostenfeld. On the basis of his comparison, Wall considered both Tasmanites and Leiosphaeridia to be fossil green algae closely related to Pachysphaera pelagica and Halosphaera minor, respectively. The broad spatial distribution and the narrow vertical distribution of these sporomorphs as recorded by Jodry and Campau (1961) and

Kent (1963, 1965) tend to agree with Wall's (1962) conclusion on the planktonic nature of these organisms.

STRATIGRAPHIC DISTRIBUTION

The type species of Tasmanites described by Newton (1875) was obtained from the "Tasmanite" and Australian "White Coal" which are according to Reed (1921) Permo-Carboniferous in age. Radforth and Rouse (1956) reported occurrences of Tasmanites in rocks of Late Devonian, Early Mississippian, Early Cretaceous and Tertiary age. Sommer (1956a) observed these sporomorphs in Silurian and Devonian strata in drill cores from an oil exploration bore hole at Bon Jardin in the town of Itaitaba, State of Para, Brazil. Jodry and Campau (1961) recorded Tasmanites from a number of horizons in the Paleozoic strata of the Williston Basin including rocks of Middle Devonian, Late Devonian and Mississippian age. Tasmanites, therefore, would appear to have a time range from Silurian to Tertiary. Eisenack (1958) suggested that Leiosphaeridia may be obtained from strata in Europe ranging in age from Late Cambrian to Early Jurassic.

Jodry and Campau (1961) were the first to publish identifications of Tasmanites (and Chitinozoa) in certain zones in the subsurface strata in western Canada and the northwestern United States. In their paper, they discussed the lateral and stratigraphic distribution of these microfossils and the use of them as stratigraphic correlation markers. They found that Tasmanites and Chitinozoa were confined to relatively thin zones in the geologic succession in the Williston Basin and adjacent areas. They observed that Chitinozoa were usually present only in the lower part of the Palaeozoic strata overlapping slightly with

Tasmanites in the Middle Devonian Series (a zone of Chitinozoa occurs in the Middle Devonian Dawson Bay Formation and the first Tasmanites zone is encountered in the underlying Winnipegosis Formation.) The stratigraphic distribution of Chitinozoa may be more complex than that presented by Jodry and Campau (1961). The writer recently found Chitinozoa in the basal beds of the upper member of the Birdbear Formation in southwestern Saskatchewan, and in the lateral equivalent of the Duvernay Formation of eastern Alberta. Staplin (1961) recorded Chitinozoa from the Duvernay Formation of central Alberta. With the exception of the occurrence of Tasmanites in the Middle Devonian Winnipegosis Formation, these sporomorphs and the associated Leiosphaeridia have not been observed in western Canada or northwestern United States in beds older than Late Devonian and younger than Mississippian Charles Formation. Until recently, all Late Devonian occurrences of the sporomorphs had been recorded from the Saskatchewan Group, but Sandberg (1964) observed Tasmanites in the Maywood Formation of southwestern Montana. The other occurrence of sporomorphs in Mississippian strata is in the Bakken Formation.

SPOROMORPHS IN THE SASKATCHEWAN GROUP

Kent (1963) recorded four zones of sporomorphs within the Duperow Formation of the Saskatchewan Group. Some of the zones had broad lateral distribution but they were not employed at that time as aids to correlation. Kent (1965) reappraised the vertical and spatial distribution of the sporomorph zones and found at least six in the Duperow and Birdbear Formations. Four of these zones, one in the Birdbear Formation, one at the base of the middle unit and one at the base of the

lower unit of the Wymark Member and one at the top of the Saskatoon Member, were found to be laterally persistent throughout much of the study area. They were traced from southwestern Saskatchewan as far west as the southern Alberta Marginal Reef Complex. The less persistent zones are in unit A of the Seward Member and near the base of the upper unit of the Wymark Member.

Kent (1965) observed that at the present time the sporomorph zones cannot be used in the same manner as other microfossil or macrofossil zones, that is, as a means of distinguishing strata by the nature of their fossil content, because it is difficult to draw any distinction between forms of the various zones. However, as further work is done on the taxonomy of these organisms, it may be possible eventually to recognize certain species as belonging to a particular zone. The main significance of these microfossil zones, then, is in their lateral persistence and stratigraphic position which make them a useful aid in distinguishing between, and identifying, lithologic marker beds (see figures 3 to 9, inclusive and figures 12 and 15).

Jodry and Campau (1961) consider the sporomorph zones to be time-parallel horizons. If the microfossils that make up these zones are phytoplankton, as suggested by Wall (1962), then the vertical recurrence of the zones could be attributed to periods of "bloom" of the particular organism from whence the sporomorphs originated, and the broad lateral extent, a result of a spreading out of the phytoplankton from their place of origin (possibly an environment similar to a Sargasso sea). At the close of their migratory stage the organisms probably released their protective covers which sank to the sea floor to be incorporated in the bottom sediments, and represented in the present sequence

of rocks by Tasmanites and Leiosphaeridia. The stages of "bloom", migration and settling of the protective cover probably occurred over a short span of geologic time, and therefore, in the author's opinion the hypothesis that the sporomorph zones are para-time horizon may be valid. The scarcity or complete absence of Tasmanites and Leiosphaeridia in some locations may be due in great part to bottom currents which washed them away before they were incorporated in the sediments.

The size of the Tasmanites of the Saskatchewan Group and its lateral equivalents varies between 40.7 microns and 92.5 microns in diameter, with wall thicknesses between 3.7 microns and 9.25 microns. The Leiosphaeridia are 22.2 microns to 99.9 microns in diameter with wall thickness between 1.85 microns and 9.25 microns. They are with a few exceptions much smaller than those described from other areas. The size range of the 10 species from the Palaeozoic of South America, which are described by Sommer (1953, 1956a, 1956b) are recorded on page 68 and are considerably larger than those found in the rocks of the Saskatchewan Group. All but one of the specimens described by Eisenack (1958, 1962) are larger than those of the present study. Only Tasmanites verrucosus Eisenack 1962 has approximately the same diameter range, but it has a pylome which has not been recognized in any specimens collected from the Saskatchewan Group. Winslow (1962) obtained a number of specimens of Tasmanites from Upper Devonian and Lower Mississippian rocks in Ohio. From these specimens she recognized four species one of which, Tasmanites sinuosus Winslow 1962, is similar in size but not in appearance to the forms collected from strata in the Saskatchewan Group. Urban (1962) collected two species of Tasmanites from the Devonian Woodford Shale of Oklahoma which are similar in both size and appearance to the Tasmanites

collected by the author. One of these he called *Tasmanites* cf. *T. hartii* Sommer and the other he described as *Tasmanites* sp. 2.

The writer has made no attempt to apply species names to the specimens collected, since he is of the opinion that detailed statistical studies are necessary before this distinction can be made.

Correlation

The correlations presented here are an attempt to determine the time relationship of the various stratigraphic units in the area of study. They are based on two criteria:

1) A comparison of the fossil content of the stratigraphic units, and
2) Marker horizons thought to be time parallel.

The fossil material collected, thus far, from the Upper Devonian subsurface strata in Alberta and Saskatchewan is sparse, with the result that detailed correlations based on the faunas are difficult to carry out. The faunal succession of central Alberta does not appear to persist in the subsurface of Saskatchewan, as is illustrated in later paragraphs. However, those regional and local correlations that employ marker horizons demonstrate an apparently meaningful time and spatial relationship between stratigraphic units. The most useful marker horizons employed in this study are the sporomorph zones. Their time-parallel significance was discussed in the previous section. In the author's opinion the close relationship between the stratigraphic position of some of the sporomorph zones and the tops or bottoms of some of the main lithologic units in the succession (e.g. the top and bottom of the Elstow Member and the top of the lower member of the Birdbear Formation) may be interpreted as indi-

cating that the lithologic changes which mark the tops and bottoms of these units may have occurred over a short span of geologic time and therefore they can be employed as time planes. In the thick non-argillaceous carbonate sequence of the Saskatchewan Group (e.g. the Wymark Member) there are thin argillaceous beds which intersect the various carbonate facies obliquely in the same manner as the non-sequential beds (Cummings et al. 1959) of the Mississippian rocks of southeastern Saskatchewan (Fuller, 1956, Porter, 1958, Brindle, 1960). These non-sequential beds are considered to be time parallel and were employed in the present study as a means of separating the Wymark Member into smaller units. There is a distinct parallelism between the non-sequential beds and the sporomorph zones of the Wymark Member. In the writer's opinion the anhydrite deposits within the Saskatchewan Group were probably developed over a short period of geologic time and may therefore be paratime marker beds. However, most of them are not useful for regional correlation because of their limited lateral distribution, with the exception of the Dinsmore Evaporite which marks the top of the Wymark Member throughout much of western Saskatchewan.

DUPEROW FORMATION

There is a distinct similarity between the fauna of the Saskatoon and Elstow Members of the Duperow Formation and those of the Flume, Maligne and Hollebeke Formations of the Alberta Rocky Mountains. Elements of this fauna also occur in the upper beds of the Beaverhill Lake Formation and throughout the Cooking Lake Formation in the subsurface of Alberta and in the lower 200 ± feet of the lower member of the Jefferson Formation of Montana. The presence of Eleutherokomma reidfordi in the

Elstow and Wymark Members just above an occurrence of E. leducensis appears to be stratigraphically lower than any previously recorded occurrence of that fossil in subsurface strata. The recorded stratigraphic position of E. reidfordi in the subsurface of Saskatchewan, if correlated with the occurrence of this fossil in the Ireton Formation of Alberta (Warren and Stelck, 1950, Crickmay, 1950) would indicate the underlying strata to be much younger than has previously been thought and would also require a major time break near the top of the Souris River Formation, since the fossils from that formation are similar to those found in the Beaverhill Lake and Waterways Formations. On the other hand, if the sporomorph zones in the lower part of the Duperow Formation are traced from Saskatchewan into Alberta, the correlations produced by using these show that the basal beds of the Duperow Formation, the lower member of the Cairn Formation of southeastern Alberta and the Cooking Lake Formation are all time equivalents (Figures 3 to 5, inclusive). With the exception of the E. reidfordi all other fossils found in these basal strata agree with this correlation. In the author's opinion the reported occurrence of E. leducensis (Powley, 1951) in strata much higher stratigraphically than E. reidfordi may be interpreted as an indication that the fossil zones which are useful in the subsurface of Alberta cannot be applied to the strata in Saskatchewan, probably because the organisms have a tendency to live in a specific environment and thus their fossilized remains are found in a particular carbonate facies.

Based on the evidence presented above, the writer proposes that the Elstow and Saskatoon Members of the Duperow Formation correlate with the Flume, Maligne, and Hollebeke Formations of the Alberta

Rocky Mountains, with the uppermost strata of the Beaverhill Lake Formation and the Cooking Lake Formation in the subsurface of the Alberta plains and with the lower 200$^{\pm}$ feet of the lower member of the Jefferson Formation of Montana.

The mixed fauna of the Wymark Member is of little assistance in correlating this unit in western Saskatchewan with stratigraphic units in other parts of the map area. The upper limit of Rhabdostichus cf. R. pulex is in the upper part of the Wymark Member in western Saskatchewan and in the lower beds of Wilson's (1955) Upper Duperow unit of the Jefferson Formation or in the middle of Sandberg's (1965) lower member. The author is of the opinion therefore that the Wymark Member is correlative to the middle strata of Sandberg's (1965) lower member of the Jefferson Formation. All other correlations of this unit will depend on the time relationship established for the overlying and underlying members.

The fauna from the Seward Member contains elements of both the Macgeea proteus and Spirifer strigosus Zones as outlined by Warren and Stelck (1954; 1956). The presence of Nervostrophia maclareni in this member may be interpreted as an indication that the Seward Member correlates with the Macgeea proteus Zone of the Escarpment Member in the Hay River Formation. The Escarpment Member has been correlated with the Duvernay Formation and the lower part of the Ireton Formation of the Alberta plains (Belyea and McLaren, 1962) and with the uppermost beds of the Cairn Formation and the basal beds of the Southesk Formation of the Alberta Rocky Mountains (Belyea and McLaren, 1962). Warren and Stelck (1956) illustrated a Macgeea proteus fauna from the lower part of the Mount Hawk Formation of the Alberta Rocky Mountains and the author

proposes therefore that the Seward Member correlates with these strata also. Because of its position above the Wymark Member the Seward Member may be correlated with the upper beds of the lower member of the Jefferson Formation.

The Wymark-Seward interval of the Duperow Formation is probably correlative with the Perdrix Formation and the lower strata of the Mount Hawk Formation and with the Cairn and lower beds of the Southesk Formation of the Alberta Rocky Mountains. This interval may also be correlated with at least the lower part of the Ireton Formation and the Duvernay Formation of the Alberta plains. The sporomorph zone at the base of the middle unit of the Wymark Member has been correlated with a zone at the base of the upper member of the Cairn Formation of southeastern Alberta. In the author's opinion this would seem to indicate that the lower unit of the Wymark Member correlates with the upper part of the Cooking Lake Formation, (Figures 3 to 6 inclusive) and that the total Wymark-Seward interval correlates with strata in the upper part of the Cooking Lake Formation through to and including the lower part of the Ireton Formation.

BIRDBEAR FORMATION

The fauna collected from the Birdbear Formation is for the most part composed of poorly preserved specimens, making it difficult to identify the species. Among those species which were identified are two species which have a broad vertical range. The occurrence of _Tenticospirifer cyrtiniformis_ in the upper member of the Birdbear Formation may be interpreted as an indication that this member correlates with the _T. cyrtiniformis_ Zone in the upper part of the Mount Hawk

Formation of the Alberta Rocky Mountains and with the upper part of the Ireton Formation in the subsurface of the Alberta plains. Both Atrypa cf. A. hackberryensis and Stropheodonta cf. S. subdemissa were collected from the lower member of the Birdbear Formation. Both of these species are found in the Spirifer strigosus Zone of the lower part of the Grumbler Group of the Hay River area, and these strata have been correlated with the upper beds of the Ireton Formation and with the Nisku Formation of the Alberta plains (Belyea and McLaren, 1962). There is a sporomorph zone near the top of the lower member which when traced westward gradually climbs to the lowest beds of the upper member. This zone was recognized as far as the southern Alberta Marginal Reef Complex where it is found in the basal beds of the Camrose Tongue. Using the evidence presented above the writer proposes that the Birdbear Formation is correlative with the upper part of the Mount Hawk Formation of the Alberta Rocky Mountains, with the lower beds of the Grumbler Group of the Hay River area and at least in part with the upper part of the Ireton Formation (including the Camrose Tongue) of Alberta plains. Because of the absence of fossils in the Torquay Formation the time relationship of the upper beds of the Birdbear and of the overlying Torquay Formation cannot be established in the usual manner, and must be determined by considering their spatial relationship in the area of investigation. However, a generalized time correlation can be established for the strata since the lower beds of the Big Valley Formation have been correlated with the upper beds of the Palliser Formation of the Alberta Rocky Mountains and with the green shales underlying the Exshaw Formation in the subsurface of the Alberta plains (Brindle and Guliov, 1965). From this faunal evidence and other previously mentioned time relationships for

the underlying strata, the author concludes that the upper beds of the Birdbear Formation and the overlying Torquay Formation may be coeval with the Winterburn Group and the Stettler Formation of the Alberta plains and with the Alexo and Palliser Formations of the Alberta Rocky Mountains. The author gives more detailed consideration to the spatial relationship of the Birdbear and Nisku Formations in another section (page 142).

Age

The lower beds of the Duperow Formation contain Eleutherokomma killeri, E. leducensis and E. reidfordi all of which are Finger Lakes Stage fossils, according to Crickmay (1950). House and Pedder (1963) suggested that the Maligne Formation of the Alberta Rocky Mountains belongs to the Pharciceras lunulicosts Zone of Europe, placing it in the lower part of the Frasnian Stage. Since the lower beds of the Duperow Formation have been correlated in part with the Maligne Formation, they are probably partly early Frasnian in age. It may be concluded from this evidence therefore that the lower strata of the Duperow Formation are early Upper Devonian in age. Elements of the Seward fauna belong to both the Macgeea proteus Zone and the Spirifer strigosus Zone of western Canada which Warren and Stelck (1956) correlated with the Calvinaria albertensis Zone of McLaren (1954). McLaren (1954) considered that his C. albertensis fauna is similar to the fauna of the Cerro Gordo beds of the Hackberry Shale and Independence Shale of Iowa and to the Sly Gap Formation of New Mexico. All of these are from the upper Chemung sequence (Cooper et al. 1942). House and Pedder (1963) correlated the C. albertensis Zone with the upper part of the Manticoceras cordatum Zone of Europe which is latest middle Frasnian in age. The Tenticospirifer

cyrtiniformis Zone of Warren and Stelck (1956) was correlated with the _C. albertensis_ Zone also. In the opinion of the author from this evidence the age of the Wymark Member is probably late Finger Lakes to early Chemung (in European nomenclature late lower to early middle Frasnian) and the Seward Member and Birdbear Formations are probably late Chemung (late middle Frasnian) in age.

Brindle and Guliov (1965) correlated the lower beds of the Big Valley Formation of the Three Forks Group with the Ouray Limestone of Colorado and the Percha Shale of New Mexico, both of which are late Chautauquan (late middle Famennian) in age (Cooper _et al_. 1942). Therefore the strata between the Birdbear Formation and the Big Valley Formation range from late Chemung to middle Chautauquan (late Frasnian to middle Famennian) in age.

SEDIMENTATION

Sedimentary Features

There are a number of sedimentary features found in the rocks of the Saskatchewan Group which could not be fully described or discussed in the stratigraphic portion of this thesis without digressing from the theme of that section. Therefore these features are considered in this section under the following headings:

1) Laminated strata,
2) Disturbed bedding,
3) Pebble beds and intraformational breccias, and
4) Solution phenomena.

LAMINATED STRATA

Laminated strata are illustrated in Plates 1 and 2 and are found in those units of the Saskatchewan Group and its lateral equivalents that are dominantly non-argillaceous carbonate rocks. Laminated strata consist of an alternating series of light and dark layers of limestones or dolomitic limestone. The limestones are extremely fine-grained and are micrites under Folk's (1959) definition. The darker layers result from an intermixture of carbonate and carbonaceous materials. They are mainly characterized by a highly carbonaceous zone near the bottom which grades upward into less carbonaceous rock. In thin section the calcite grains in the dark layers are generally masked by the carbonaceous material, but where the rock has been dolomitized, the euhedral dolomite rhombs are plainly visible and abundantly dispersed throughout. The light layers, on the other hand, commonly have a lower proportion of dolomite rhombs and do not appear to

have been as susceptible to dolomitization as the dark layers. This is in direct contrast to observations made by Newell et al. (1953) for laminated strata in the Permian rocks of west Texas, where the lighter layers are more dolomitic than the darker ones. Although the light layers are mainly composed of micrite, some have been found to be pelletoid. These laminated sequences are generally characterized by intervals of thinly laminated beds with well-defined laminae alternating with carbonates that are non-laminated or have poorly developed laminae. The cored interval from the Pan American A-1 West Saskatoon No. 14-10 well (Lsd. 14-10-35-7W3) illustrates this type of succession, where laminated and non-laminated intervals vary widely in thickness between 6 inches and 7 feet.

It is difficult to give an accurate estimate of the thickness of the individual laminae since some are extremely thin and somewhat irregular. Generally the dark, carbonaceous, layers are thinner than the light, non-carbonaceous, laminae. The thinnest laminae are slightly less than 0.5 mm. and the thickest is about 10 mm. Rarely as is illustrated in Plate 1, Figure 3 and Plate 2, Figure 1, lamination is interrupted by thin beds of non-carbonaceous or carbonaceous material which are slightly thicker (14 mm. to 18 mm.) than the defined upper limit for laminae (10 mm., American Geological Institute, 1960). Some of the thinner non-carbonaceous laminae are rarely disrupted and produce sedimentary boudinage structures, as shown in Plate 1, Figures 2 and 3. Both the dark and the light layers in some instances have been truncated, possibly indicating a minor period of erosion which interrupted the sedimentation.

The origin of finely stratified deposits remains a matter of

speculation. Newell et al. (1953) suggested that similar sediments observed in the Permian rocks of west Texas may have been deposited by turbidity currents. The laminated beds described by Newell et al. (1953) seem to have been laid down in a basinal environment but the writer is of the opinion that the laminated sediments of the Saskatchewan Group formed in an environment of relatively little wave action and are possibly lagoonal. The micritic nature of these rocks would seem to favour this hypothesis; most workers believe rocks of this grain size to have been laid down in areas with little wave agitation. The carbonaceous layers probably represent cyclic influxes of organic material. Whether they represent seasonal, annual or another type cycle is still uncertain. Newell et al. (1953) were not convinced of the seasonal or annual nature of the dark and light layers in the laminated deposits of the Permian basin of west Texas, because they were of the opinion that the thickness of pairs of laminations in the Permian rocks was greater than that to be expected during annual accumulation.

DISTURBED BEDDING

Within the rocks of the Saskatchewan Group, there occurs a group of sedimentary features which have one attribute in common: the strata that contain them have all been disrupted or disturbed. However, the origin of each type of features may be slightly different. These features include:

1) Contorted bedding,
2) Sedimentary boudinage, and
3) Indistinct stratification.

<u>Contorted Bedding</u>. Contorted bedding seems to be most common in the laminated or thinly stratified rocks of the Saskatchewan Group. There are two main types, illustrated by the box and recumbent folds in Plate 2, Figures 3 and 4 and the micro-thrust fault in Plate 2, Figure 1. These structures are usually produced in beds not exceeding 3 inches in thickness.

It is difficult to reach a conclusion concerning the origin of these structures since the cores in which they are found present a very narrow view of the phenomena. Newell <u>et al</u>. (1953) interpret similar structures in the Permian rocks of West Texas, as the result of slumping and intrastratal flowage due to downslope creep. They indicate that some of the structures were produced on slopes no greater than 1 or 2 degrees. Twenhofel (1932) noted that sliding has been known to take place on slopes with inclinations as low as 2° 31'. In the writer's opinion the sediments which would flow down a slope of 1 or 2 degrees would probably be in a semi-fluid state, but the ruptured beds in all three illustrated structures formed in the sediments of the Saskatchewan Group suggest that the strata involved were relatively well consolidated when the folding and thrust faulting took place. Therefore, the author favours the hypothesis that the structures were produced after burial and during compaction. Bradley (1931, pp.26-28) ascribes this origin to similar structures produced in the laminated sediments of the Green River oil shale. He concluded that "....it seems likely that contorted bedding due to differential stresses during compaction would be most commonly localized in beds that contained an abundance of organic matter, a relatively large proportion of micaceous clay minerals, and an unusually fine-grained mineral aggregate".

Sedimentary Boudinage In the rocks of the Saskatchewan Group, sedimentary boudinage is best developed in thin limestone beds overlain and underlain by calcareous or carbonaceous shales (Plate 3, Figure 1 and 2). The structure, however, is not confined to this type of sequence and they are found also in thinly interbedded non-argillaceous and argillaceous limestone (Plate 4, Figures 1 and 2). Sedimentary boudinage is characteristic of the Elstow Member and of subunit B1 of the Seward Member. It is also common in the shaly facies of the Saskatoon Member and in the lower member of the Birdbear Formation.

These "pinch and swell" structures, as they are sometimes called, appear to depend on the relative competence of the interlayered rocks, which may be a function of the thickness of the beds involved, the difference in lithologic composition between layers, or the difference in the grain size of the layers affected. In the rocks of the Saskatchewan Group the best-defined structures are found where the lithologic composition of the interlayered rocks is significantly different, as in Plate 3, Figure 1 where the "pinch and swell" structures are present in pelletoidal micritic limestone layers interbedded with carbonaceous shales. In contrast, those sedimentary boudinage structures shown in Plate 4, Figures 1 and 2, were formed in a sequence of alternating layers of argillaceous and non-argillaceous, fossiliferous micrite. The argillaceous layers are strongly dolomitized and commonly contain more than 50 percent 0.03 to 0.04 mm. dolomite rhombs. The irregular nature of the boudins occurring in this second type of lithologic association is probably due to the similarity of the rock types involved, and the presence of argillaceous material in some of the beds is probably the main reason that "pinch and swell" structures were formed in the

specimens (see also "Solution Phenomena" p. 92).

Plate 5, Figures 1 and 2, illustrate the manner in which the thickness of the layers can affect the formation of sedimentary boudinage. In the previous examples there was little difference between the thickness of the layers, but in Plate 5 the limestone beds are generally much thicker than the carbonaceous shale partings, and the limestone strata show only minor irregularities.

McCrossan (1958) concluded that sedimentary boudinage was a compaction phenomenon produced in semi-consolidated sediments overlying the crests of swells on the sea floor. He illustrated structures found in the Upper Devonian Ireton Formation of central Alberta which closely resemble the structures illustrated in this paper. McCrossan (1958) felt that the extra stress exerted on beds on the crests of the swells due to overlying strata may cause the finer - grained, less competent, beds to flow thus creating tensile stresses in the coarse-grained, more competent, beds. As compaction and plastic flowage of the incompetent beds continued, the competent beds became disrupted and the "pinch and swell" structures evolved. That tensile stress was produced in the competent strata can be deduced from the presence of small fractures formed in these beds which appear to be tension fractures. When viewed in thin section the fractures are seen to be infilled by sparry calcite or anhydrite. These tension fractures are illustrated in Plate 3, Figure 1.

<u>Indistinct Stratification</u> Indistinct Stratification is illustrated in Plate 6, Figures 1 and 2. It appears to be preserved only in the more argillaceous strata and has been observed in cored intervals obtained from the Seward Member of the Duperow Formation.

The two specimens that illustrate this phenomenon are composed of similar materials but in slightly different proportions. The specimen in Plate 6, Figure 1 consists of highly argillaceous, microcrystalline calcareous ooze with scattered crinoid columnals and ostracod valves. The specimen in Figure 2 of the same plate is somewhat more argillaceous and less calcareous, also no fossils were observed in thin sections of this specimen. Indistinct and irregular stratification are well illustrated in both specimens.

The writer is of the opinion that indistinct stratification is the result of the sediments having been reworked by burrowing and scavenging organisms on the sea floor. Harms (1966; pp. 2130-2131) illustrates structures with a similar appearance but formed in non-calcareous clastic sediments. He also attributes them to organic burrowing and scavenging. Illustrations of an experiment by Ginsburg (1957; Figure 8, p. 87), show how oligochetes can destroy primary stratification in calcareous sediments by burrowing. These illustrations leave some doubt as to whether the structures illustrated in Plate 6 are the result of organic burrowing. However, the author feels that whether the stratification is completely obliterated or is just indistinct may be a function of the composition and grain size of the sediments involved.

PEBBLE BEDS AND INTRAFORMATIONAL BRECCIAS

The pebble beds are thin layers of well-rounded to subangular, flat or irregularly-shaped pebbles (some of which are illustrated in Plate 7, Figures 1 and 2), similar in appearance in some instances to the intraclasts illustrated by Folk (1962, Plate 1-A, p. 77). The

clasts have a wide size range between 1.0 mm. and 32.0 mm., encompassing the very coarse sand to pebble sizes of the Wentworth scale (Pettijohn, 1957, p. 18). However, for simplicity all sizes observed in this study are called pebbles. They are composed of very fine-grained (micritic) limestone similar in composition to either the matrix or underlying sediments. All pebbles have a thin outer coating of finely disseminated pyrite and some have pyrite distributed completely through them. In the cores observed the pebbles generally have no distinctive distribution, but occasionally they have been seen in an imbricate pattern. Finely comminuted fossil debris, including crinoid columnals and fragmented brachiopod shells are commonly associated with the pebbles.

The term intraformational breccia pertains only to those breccias the fragments of which were formed shortly after deposition, and do not include solution collapse breccias which were produced after burial and lithification. In the rocks of the Saskatchewan Group intraformational breccias consist of angular to subangular, often elongate, fragments of limestone or dolomite in a matrix of similar composition (Plate 7, Figure 2). The breccia fragments and matrix material may be either argillaceous or non-argillaceous carbonate.

In the author's opinion the pebble beds and the intraformational breccias may be interpreted as a result of short periods of non-deposition and erosion, i.e., diastems. The pebbles and breccia fragments may have been produced by one of two methods; subaqueous fragmentation, or shoaling accompanied by dessication and fragmentation of the dessication products (Pettijohn, 1957, p. 277). The pebble beds may in fact represent locally developed strand line deposits, particularly in view of the fact that large concentrations of fossil debris

are associated with them, giving the appearance of a winnowed deposit. The burrows illustrated in Plate 7, Figure 1 are infilled with pebbles and fossil debris, which in the opinion of the writer adds weight to the hypothesis that the pebbles were formed by fragmentation of newly deposited sediments during a period of non-deposition and erosion. The burrows were probably made within a few inches of the sediment surface and then filled with pebbles and fossil debris. The breccia illustrated in Plate 7, Figure 3, may have been produced by fragmentation of the products of dessication, since the long, thin fragments are similar in shape to those produced by disintegration of present day mud polygons. Some of the other intraformational breccias found within the Saskatchewan Group may have been formed subaqueously.

SOLUTION PHENOMENA

Throughout the rocks of the Saskatchewan Group there is plentiful evidence indicating that some of the strata have been removed by solution. Solution may be represented in these rocks by one of two features: stylolites or solution collapse breccias.

Stylolites are the most common solution phenomenon and are in two forms: 1) classical serrated sutures, and 2) incipient or microstylolites as illustrated in Plate 8. Serrated sutures are not abundant in the Saskatchewan Group, and where present they rarely exceed 2 inches in vertical dimension. The more common incipient stylolites are generally wavy or irregular surfaces which appear in vertical cross section as hairline partings of insoluble residues (Plate 8). They may be found either as a single parting, as in Plate 8, Figure 2, or closely packed partings producing a zone of incipient stylolites as in the upper por-

tion of the specimen in Plate 8, Figure 1. Incipient stylolites do not appear to be confined to any particular rock type, but are commonly found at the upper contact between algal nodules, stromatoporoids or other resistant objects and the enclosing carbonate sediment. The insoluble residue is strongly concentrated at the apex of the resistant object or fossil, draped over it and feathered-out into numerous hairline partings.

Pettijohn (1957, p. 412) noted that the significance of stylolitization is in the fact that appreciable volumes of carbonate material may be removed and primary textures may be altered or modified. The latter condition is illustrated in Plate 12, Figure 1, which shows that the pellets of a pelletoid micrite have been obliterated in the microstylolite zone. The writer noted also that incipient stylolite zones in the carbonate rocks of the Saskatchewan Group are commonly areas of strong dolomitization (Plate 12, Figure 2). In many instances the rocks on either side of the stylolitic zone may be undolomitized or only partially dolomitized. The zones, then, probably permit freer circulation of magnesium-rich formation waters than do the portions without stylolites. Microstylolite development may represent also the first stage in the formation of some sedimentary boudinage structures, particularly those illustrated in Plate 4. Primary compaction pressures may have resulted in the formation of incipient stylolitic zones; once formed any further compaction pressure may have produced lateral movement in the microstylolitic zones creating tensional stresses in the layers not affected by stylolitization, and resulting in the "pinch and swell" structures shown in Plate 4.

Solution collapse breccias have been observed in the cores of

wells in various parts of the area of study, as well as in outcrops of the Jefferson Formation in Montana. Most of these breccias are confined to relatively thin zones within a formation or member and in this paper are referred to as intrastratal breccias; however, some wells show that thick portions of the Saskatchewan Group, and in some instances other Devonian stratigraphic units have been brecciated. These breccias may be called transformal breccias in the terminology of Landes (1945). The transformal breccias appear to be a result of the removal by solution of the Middle Devonian Prairie Evaporite or younger evaporites and the collapse of the overlying strata. This type of brecciation is present at the Tidewater Braddock Crown No. 1 well (Lsd. 5-7-14-10W3) and is the phenomenon which makes the determination of the formation and member tops a difficult task in this well.

Intrastratal breccias are commonly composed of a lower portion containing a mixture of carbonate fragments, such as is illustrated in Plate 9, Figure 1, and an upper portion of a single lithologic type. However, the fragments of the breccias in the Jefferson Formation are very often oligomictic (Plate 9, Figure 2). When observed in thin section the breccia fragments from the Jefferson Formation are found to be composed of fragments from earlier breccias. This is similar to the findings of Middleton (1961) who studied solution breccias in the Mississippian strata of Montana. The breccia fragments have a broad range between about 0.5 mm. and 40 mm., but it is difficult to establish size limits for fragments and matrix since the latter contains both rock flour and microscopic rock fragments not visible to the unaided eye. In some of the breccias from the Jefferson Formation there is little actual matrix material and the original void spaces between the fragments have

since been infilled by sparry calcite. Thin carbonaceous partings cut obliquely through the breccias found in cores and are generally highly polished giving the appearance of slickensiding.

The writer is of the opinion that at least three criteria of cataclastic origin can be applied to solution collapse breccias. These are:

1) Stratigraphic position. Middleton (1961) employed the criterion of stratigraphic position to breccias in the Mississippian strata of Montana. It is particularly applicable to the breccias found at the base of the Seward Member and at the top of the Wymark Member as encountered in a number of potash shaft coreholes drilled in the Saskatoon area. In several other wells that were drilled south and west of this area, a sequence of interbedded anhydrites and carbonates is present at the same stratigraphic level as the breccias of the Saskatoon area, In the author's opinion these anhydrites at the base of the Seward Member and the top of the Wymark Member originally extended into the Saskatoon area, but following removal of the Saskatchewan Group strata from the area north of Saskatoon during a post-Devonian pre-Cretaceous erosional interval, were uncovered, weathered and consequently leached. Following the removal of the evaporites the overlying and interbedded carbonate layers collapsed to form the breccias found in the various cores from this area. Middleton (1961) pointed out that the breccias he studied were formed only after the Mississippian carbonates and evaporites had been exposed to weathering, _i.e._ they are post-Laramide orogeny.

2) The presence of thin partings of carbonaceous material in the breccias may be interpreted as an indication that pressure-solution mechanisms were active in these rocks, probably during the collapse

stage. The highly polished slickenside-like surface in the partings lend support to the hypothesis that movement occurred in these rocks along the partings.

3) Like the breccias described by Middleton (1961) the solution collapse breccias of the Saskatchewan Group have a well-defined base, and there is usually a gradation upward from a highly mixed breccia containing a variety of carbonate fragments to an area of little movement where the breccia fragments are oligomictic.

In the case of the brecciated strata observed in the Tidewater Birsay Crown No. 1 well (Lsd. 13-4-25-8W3) two of the three above mentioned criteria can be applied, which suggests a solution collapse origin. However, there is no evidence from surrounding wells that evaporites are present at the same stratigraphic level as the brecciated beds. Thus, the breccias in this well remain as something of an enigma.

Diagenetic and Post-Diagenetic Alterations in the Carbonate Rocks

A microscopic petrographic examination of the carbonate rocks of the Saskatchewan Group revealed that microcrystalline ooze material (micrite of Folk, 1959) was the most common rock type. The micrite is generally the matrix material surrounding fossil debris (brachiopod fragments, ostracod valves and carapaces, crinoid columnals) and pellets. In the thin sections examined the fossil material is never sufficiently abundant to be self-supporting, that is to say the micrite matrix in all instance appear to be binding the fossil material. On the other hand the pellets were often observed to form a self-supporting lattice with sparry calcite infilling the void spaces between the pellets.

Rocks built by organisms such as algae and stromatoporoids

were seldom observed in unaltered form, but in the author's opinion the rhombic dolomites mentioned in the stratigraphic portion of the text, and outlined in Figures 12 and 14, may in some instances represent the dolomitized end-product of a reef or organically-supported rock.

Because most of the carbonate rocks examined have undergone various diagenetic and post-diagenetic changes the writer feels that it is necessary to discuss them and show their effects. These alterations include: 1) recrystallization (in the sense of Folk, 1965, pp. 20-21), 2) dolomitization, and 3) other mineralization.

RECRYSTALLIZATION

The recrystallization processes which acted on the carbonate rocks of the Saskatchewan Group include grain enlargement (aggrading neomorphism of Folk, 1965); degrading recrystallization (Folk, 1965) or grain diminution (Orme and Brown, 1963); fibrous calcite development; and natural mold formation.

Grain Enlargement Most of the calcite observed in the thin sections of these carbonate rocks appears to have undergone some recrystallization. For example, most of the microcrystalline ooze material consists of grains somewhat larger than the maximum size limit for micrite as proposed by Folk (1959), *i.e.*, 4 microns. They are, instead, between 5 and 30 microns, and mainly 5 to 15 microns (microspar of Folk, 1965). Folk (1965) interpreted this grain size as the product of the recrystallization of micrite. However, other workers (Bathurst, 1958 and 1959; Banerjee, 1959; and Nichols, 1966) considered grains of this size to have been formed by the mechanical disintegration of larger carbonate fragments. Their conclusion that calcite silt could be the product of

mechanical disintegration was substantiated by Matthews (1966, pp. 433-443) who noted the presence of abraded carbonate material of silt size in shoal and lagoonal sediments off the coast of southern British Honduras. It would appear from the observations of the above mentioned workers that under certain circumstances silt-size calcite grains in some carbonate rocks may be the result of mechanical disintegration, but in the opinion of the writer the silt-size calcite observed in the carbonate rocks of the Saskatchewan Group has been produced by recrystallization of microcrystalline carbonate ooze. This conclusion has been made from the fact that no broken oolites, pellets or fossil particles were observed in the silt-size grains of the Saskatchewan Group, in contrast to the silt size grains of Matthews' (1966) study which are mainly fossil fragments.

The sparry calcite which commonly fills the void spaces between pellets in many of the thin sections of this study consists of large grains and shows no gradation in grain size outward from the walls of the pellet into the inter-pellet region, as is the usual case with primary void-filling calcite (Bathurst, 1958; Harbaugh, 1961; and Orme and Brown, 1963). The writer interprets this as an indication that the primary void-filling calcite has been recrystallized and in the process the smaller grains, which commonly encrust the outer surface of the pellets, were cannibalized by the larger grains. Rarely, sparry calcite-cemented pellets occur in the same thin section as microspar. Where this happens, and the sparry calcite cement is recrystallized, it may be concluded that the microspar is also a product of recrystallization. The age of recrystallization of the micrite and sparry calcite cement is difficult to assess from a microscopic study.

Degrading Recrystallization. During recrystallization the constituent particles, such as pellets or oolites and fossil remains, are converted to smaller grains, a process known as grain diminution or degrading recrystallization (Wardlaw, 1962; Orme and Brown, 1963; and Folk, 1965). In the present study, the writer has observed in thin section both pellets and crinoid columnals which have undergone partial recrystallization to microspar. Rock building organisms, such as algae and stromatoporoids, and organic particle and pellet supported rocks (i.e. those in which the organic particles or pellets make up the framework of the rock, Dunham, 1962) may be totally converted by this type of recrystallization, resulting in concentrations of euhedral calcite grains having a size range between 25 to 250 microns and a variable thickness and lateral extent, depending on the dimensions of the original accumulation. This type of recrystallization may have more effect on the rock-building organisms, since Ginsburg (1957) found some of the Pleistocene Key Largo reefs in Florida to have been completely recrystallised to calcite rhombohedra. The occurrence of concentrations of calcite rhombohedra in the Saskatchewan Group is less common than that of dolomite rhombohedra but the rhombic dolomites may be a replacement product of the former, since Carozzi (1960) observed that euhedral calcite can be replaced by euhedral dolomite. The more common euhedral dolomites have been interpreted as representing the highly dolomitized product of an organic framework or non-skeletal sand (oolites or pellets) (Thomas, 1962). Further consideration is given to this subject in a later section (see Dolomitization, p. 102).

Fibrous Calcite Formation. The formation of fibrous calcite is discussed as a separate subject because, the writer noted that it can be partly

due to grain enlargement and partly due to void filling, and when it has reached an extreme stage, it can result in degrading-recrystallization of fossil particles. Bathurst (1958), Orme and Brown (1963), and Jones (1965) considered fibrous calcite to be a grain growth phenomenon, and Folk (1965) described it as an example of degrading recrystallization. Fibrous calcite is most commonly found in micritic limestones where it occurs in two forms:

1) A cluster of radially developed crystals which when observed in polarized light in thin section produce a pseudo-uniaxial extinction cross (Plate 12, Figure 3).

2) A group of parallel crystals which are perpendicular to, and extended into, the matrix on either side of a common line, and which exhibit undulatory extinction in polarized light.

When recrystallization has reached an extreme stage the line between the crystals may be obliterated and the crystals become syntaxial.

The radially developed fibrous calcite may be the product of recrystallization of pellets as is shown by Figure 3, Plate 12, in which some pellets appear to be partially recrystallized to radial fibrous calcite. Cayeux (1935) and Beales (1965) also noted that pellets may be recrystallized to radial fibrous calcite.

The second type of fibrous calcite is probably the product of the recrystallization of fossil fragments or shells. It appears to commence as an encrustation or fibrous calcite replacement rim on a fossil particle, and may be either a result of grain enlargement or void filling or both forming symchronously (Plate 12, Figure 4 and Plate 13,

Figure 1). Further recrystallization results in the degradation of the fossil particle as shown in Plate 13, Figure 2; and eventual obliteration of any evidence that the fibrous calcite was formed on a fossil fragment (Plate 13, Figure 3).

<u>Natural Mold Formation</u> Natural molds are the products of solution of fossil material or nonskeletal material from carbonate rocks, and have been observed in the cores from various wells throughout the region of study. Friedman (1964) observed that during subaerial exposure oolites and other particles may be partially or entirely leached out of a bed, leaving a mold of the leached particle in the affected area. Leaching usually occurs where meteoric waters are able to percolate through the exposed rocks. According to Friedman (1964) fossil remains are the most susceptible to leaching followed by oolites, pellets and "cryptocrystalline grains" (intraclasts ?). When formed the molds are infilled by a drusy calcite mosaic which is surrounded by a micritic envelope. In the case of these leached zones in the carbonates of the Saskatchewan Group, the matrix material is usually dolomitized at some later stage with the result that the drusy calcite in the molds is either leached or dolomitized also.

DOLOMITIZATION

The carbonate rocks of the Saskatchewan Group and their lateral equivalents in contiguous areas have been affected by dolomitization to varying degrees. For example, the upper member of the Birdbear Formation is highly dolomitized throughout the area of study; on the other hand the Elstow and Saskatoon Members of the Duperow Formation are only locally affected.

Post-diagenetic dolomitization, that is dolomitization which occurred after consolidation of the rocks, appears to have been the common process, but some evidence does exist which indicates that early-diagenetic dolomite was also formed.

Two criteria may be employed to distinguish between early-diagenetic and post-diagenetic dolomites:

1) Grain size. Most post-diagenetic dolomites are much coarser than early-diagenetic dolomites.

2) Primary structures and particles (fossils and non-skeletal sand). In post-diagenetic dolomites primary structures and particles are either obliterated or poorly preserved as relicts or badly corroded remnants, whereas in early-diagenetic dolomites the structures and particles are usually well preserved.

Deffeyes et al. (1965) observed dolomites containing normal marine faunas of Plio-Pleistocene age on Bonaire in the Netherland Antilles with grains between 40 and 80 microns. These dolomites were attributed to downward-flowing hypersaline waters, and were contrasted with the recent dolomites deposited in the lagoonal areas of this island which contained crystals of about 2 microns. Illing et al. (1965) examined penecontemporaneous or early diagenetic dolomites in the shallow near-shore waters of the Persian Gulf and found the grains to be 1 to 5 microns in size. Shinn et al. (1965) found that dolomites formed in the supratidal areas of Andros Island contained grains between 1 and 2 microns. It can be interpreted from these observations that post-diagenetic or late - diagenetic dolomites may have grain size at least

in the order of 40 to 80 microns and early-diagenetic dolomite in the order of 1 to 5 microns.

Most of the dolomites examined in the Saskatchewan Group contain crystals that are from 4 to 250 microns. Partially dolomitized microspar commonly consists of dolomite rhombs between 10 and 80 microns averaging in the range of 25 to 50 microns. Partially dolomitized rock building organisms have dolomite grains between 25 and 250 microns but most commonly between 50 and 100 microns. Rocks in which the primary structures and particles are well preserved have dolomite grains in the order of 4 to 9 microns. In the author's opinion the dolomite grains between 10 and 250 microns are produced by late or post-diagenetic dolomitization and those grains between 4 and 9 microns result from early-diagenetic dolomitization. Further evidence for the post-diagenetic origin of the rhombs in the microsparitic rocks may be inferred from the concentration of 10 to 80 micron dolomite rhombs in microstylolitic zones in them (Plate 12, Figure 2). Since stylolitization is generally considered to be a post-consolidation process, then the dolomite rhombs formed in the microstylolitic zones must be post-consolidation, and since they are similar in size to rhombs dispersed through the microspar then the latter were probably formed after consolidation also.

According to Fairbridge (1957) mottled carbonate rocks can usually be interpreted as representing early-diagenetic dolomitization which was interrupted. However, in the case of those carbonates of the Saskatchewan Group which show a mottled pattern (Plate 10, Figure 1) the coarseness of the dolomite grains in the lighter patches appears to be an indication of post-diagenetic replacement. In the author's opinion the mottling is a local replacement phenomenon controlled by the physical

characters (porosity and permeability) of the rock where the mottled pattern is developed.

The mechanism by which the rhombic dolomites are formed is not clear. As was previously suggested (Recrystallization, p. 98) they may be the result of replacement of euhedral calcite grains by euhedral dolomite. On the other hand they may be due to direct and extreme dolomitization of an organic framework or of a non-skeletal sand as proposed by Thomas (1962). Murray (1960) suggested that extreme dolomitization would tend to produce a mosaic of interlocking dolomite grains rather than an accumulation of euhedral grains with extremely good intergranular porosity. In his opinion the process by which rhombic dolomite accumulations are produced consists of growth of randomly orientated dolomite crystals and solution of the remnant calcite patches, either concomitant with the growth of dolomite rhombs, or proceeding their development. The author's microscopic examination of one of the rhombic dolomite developments did not lead to any further evidence concerning the genesis of the rock, but it was noted that both rhombic and mosaic dolomite are present in the accumulation, which might be interpreted as meaning that extreme dolomitization was, in fact, the process which produced these accumulations.

Distribution of Dolomite in the Saskatchewan Group It may be noted here that many of the strata that are illustrated as consisting of limestone in Figures 12 and 15 may have been partially dolomitized, but for the sake of simplicity only those rocks which could be recognized as dolomite were shown as such in the diagrams. It can be seen from Figures 12 and 15 that dolomitization has affected each of the stratigraphic units of the Saskatchewan Group to some extent. In the Duperow Form-

ation dolomite is somewhat irregularly distributed. The lower part of the Duperow Formation, including the Saskatoon and Elstow Members and the lower unit of the Wymark Member, contain only locally developed dolomite. The middle unit of the Wymark is generally dolomitic in the upper few feet but otherwise dolomite is confined to areas where evaporitic deposits are present, as in the vicinity of the Alberta-Saskatchewan interprovincial boundary in west-central Saskatchewan (Figure 12) and to the rhombic dolomite accumulations in the unit. The upper unit of the Wymark Member is predominantly composed of evaporitic deposits and dolomites in central western Saskatchewan. This association of evaporites and dolomite has been noted by various authors in both recent and ancient sediments (Graf, 1960; Deffeyes *et al.*, 1965; and Kinsman, 1965). In the southern part of western Saskatchewan and in Montana, where the evaporites are not as significant, the upper unit is increasingly more calcareous. With the exception of subunit B2, the Seward Member is primarily composed of limestone throughout most of western Saskatchewan. However, the entire member is dolomitic in north-central Montana (Figure 15). With the exception of the lower part of the Cairn Formation, the stratigraphic equivalents of the Duperow Formation in eastern Alberta are predominantly composed of dolomite. Rhombic dolomite is dominant in the southern Alberta Marginal Reef Complex and extends eastward from there as much thinner developments (Figures 12 and 15).

The lower member of the Birdbear Formation consists of limestone in the southern, eastern and central portions of western Saskatchewan, but toward the west it becomes dolomitic (Figure 12). The upper member is highly dolomitic throughout the entire area of study with the exception of a few locations along the eastern side of the

map area where this member consists totally or partially of limestone. Beyond the eastern limits of the study area the Birdbear Formation contains large amounts of limestone (R.A.H. Nichols, personal communication) especially in eastern Saskatchewan. Thin sections show that dolomitization of the upper member in the eastern part of western Saskatchewan is irregular. A few of the thin sections show complete dolomitization but in some localities as much as 50 percent of the rock may consist of limestone. This is in contrast to the upper member of the Birdbear Formation in the rest of western Saskatchewan where thin sections show these strata to be strongly dolomitized.

The significance of the distribution of dolomite in the Saskatchewan Group and its stratigraphic equivalents is not readily apparent. Much of it may be due to the percolation of magnesium-rich hypersaline waters through the rocks. In some respects, the mechanism may be similar to the process of reflux dolomitization described by Newell et al.(1953), Adams and Rhodes (1960) and Deffeyes et al.(1965), but on a much larger scale. In eastern Alberta the highly dolomitized reef complex and extensive dolomitic strata east and south of it may be due to magnesium-rich fluids expelled from the shales of the Ireton Formation. A similar mechanism was postulated by Illing (1959) to account for the dolomitization of the reefs of the Leduc Formation in central Alberta. The finer-grained dolomites related to the anhydrite deposits are probably early diagenetic dolomites formed under sabkha-like conditions (Deffeyes et al., 1965; Illing et al., 1965; Shearman, 1963; Wells, 1962).

Dolomitization of the Birdbear Formation may be at least in part due to subaerial exposure of the carbonate rocks which make up that formation during the time that the sediments of the Torquay Formation

were being formed. Hypersaline conditions appear to have existed during part of the time that the Torquay Formation sediments were deposited and some of these hypersaline waters may have filtered through the original calcium carbonate of the Birdbear Formation producing dolomite. However, the absence of dolomite over large portions of the area east of the map area, where the similar hypersaline conditions existed when the Torquay Formation was formed, is something of an enigma.

OTHER MINERALIZATION

The most common accessory minerals in the rocks of the Saskatchewan Group are the following:

1) Secondary silica
2) Secondary anhydrite
3) Pyrite.

Secondary Silica Secondary silica was noted in several thin sections of rocks taken from the stratigraphic units of the Saskatchewan Group. It was most often observed in strata of the Wymark and Seward Members of the Duperow Formation and from the upper member of the Birdbear Formation. The silica in the upper member of the Birdbear Formation may have, in fact, some stratigraphic significance since it was observed at about the same stratigraphic position in the cores of three widely separated wells - - Tidewater Parkbeg Crown No. 1 (Lsd. 10-32-18-3W3), Tidewater Morse Crown No. 1 (Lsd. 16-25-16-8W3), and Imperial Tidewater Climax 6-10-5-18 (Lsd. 6-10-5-18W3).

In most of the thin sections which contain silica it is associated with carbonates and anhydrite, and is for the most part only a minor constituent comprising between 0.25 to 1 percent of the total

constituents observed in the thin sections. In three thin sections silica made up as much as 25 to 75 percent of the rock and in one sample the thin section had between 85 and 90 percent silica. The latter sample was taken from an interval in the Imperial Tidewater Climax 6-10-5-18 well which was highly silicified over a thickness 1.1 feet between 5708.6 feet and 5709.7 feet.

The silica is in at least two mineral forms, chalcedony and quartz, each of which may have a variety of crystal fabrics. Most of these fabrics have been discussed by various workers including Pelto (1956), Biggs (1957), Pittman (1959), West (1964) and Wilson (1966). Most of the terms employed in this study to describe the various fabrics were used by one or more of the above authors. These fabrics include:

1) Spherulitic chalcedony
   a) solitary
   b) coalesced
2) Blade chalcedony
3) Granular clusters
4) Microcrystalline quartz
5) Euhedral Quartz crystals

Spherulitic chalcedony consists of a polygonally-shaped cluster of fibrous-appearing silica grains which are orientated in such a manner that they produce a pseudo-uniaxial extinction cross centered at the common intersection of the silica grains (Plate 13, Figure 2). According to Wilson (1966) the bars of this pseudo-uniaxial extinction cross are only sharply defined when the section passes through the center of the spherulites, otherwise the grains show a blurred radial extinction pattern. In plain transmitted light the spherulites may be

clear but generally have a brownish coloration which may extend through most of the spherulite (Plate 13, Figure 3). Pelto (1956) considered the brown coloration to be an optical phenomenon due to the scattering of light by small water filled cavities in the chalcedony which cause the blue component of light to be dispersed. The absence of the blue component then produces the brownish color observed. Solitary spherulitic chalcedony may consist of a single spherulite or of a few spherulites which have intergrown to form isolated clusters of silica in a matrix of carbonate or anhydrite. Where the spherulites intergrow the extinction cross is only partially developed. Coalesced spherulitic chalcedony, as the name implies, is composed of large areas of spherulites joined together at their edges (Plate 13, Figures 4 and 5). In hand specimen this type of chalcedony may be in the form of a large silicified patch or dyke-like strips cutting randomly through a rock composed of anhydrite and minor amounts of carbonate. Coalesced spherulitic chalcedony differs from intergrown spherulitic chalcedony in that each cluster of the former is a separate entity showing a well developed pseudo-uniaxial extinction cross.

Blade-type chalcedony has a fibrous appearance also. It is commonly in the form of an arched blade (Plate 13, Figure 6) but has been noted also in the form of a straight blade (Plate 14, Figure 2). A third type, which appears to be related to the arched blades, is a subcircular or ovate silica development surrounding numerous carbonate and anhydrite grains as illustrated in Figures 1 and 3, Plate 14 or surrounding a single grain as in Figure 4, Plate 14. The arched blades are probably incomplete forms of the subcircular or ovate fabric. Like the latter two fabrics, the enclosures of the arched blades contain carbonate

and anhydrite crystals. Sometimes a small spherulite of chalcedony surrounded by carbonate and anhydrite grains is present also.

The granular clusters (Plate 14, Figure 6) are aggregates of quartz grains which show no pseudo-uniaxial extinction bar, but have a blurred radial extinction. They probably represent spherulites which have not been sectioned through their centers.

Microcrystalline granular quartz has been recognized in small patches in the coalesced spherulitic chalcedony and is the dominant type of silica in the silificied interval in the Imperial Tidewater Climax 6-10-5-18 well (Lsd. 6-10-5-18W3). It consists of interlocking grains of quartz (Plate 15, Figure 1) or well defined polygonal grains. Both of these grain types have undulose or sharp extinction under crossed nicols. According to Pittman (1959) the distinguishing feature between microcrystalline granular quartz and spherulitic chalcedony is the absence of waterfilled cavities in the former. Some granular clusters may be composed of microcrystalline granular quartz (Plate 15, Figure 2). In the illustrated example the cluster has replaced an aggregate of carbonate grains the outlines of which are relict features in the quartz. Euhedral quartz crystals having typical prismatic habit are occasionally associated with microcrystalline granular quartz (Plate 15, Figure 3).

The first step in the silicification of these rocks is the formation of nuclei from which replacement of the carbonate material can then spread. Biggs (1957) suggested that nucleation occurred in the intergranular spaces and on the outer surfaces of a carbonate grain. He noted that once the silica has filled the interstices it then commences to replace the carbonate grains. The author has found that for spheru-

litic chalcedony nucleation commences at the corner or along one edge of a dolomite rhomb (Plate 15, Figure 4). In the illustrated example the replacement is incomplete. It appears that replacement is isovolumetric since the quartz is producing a well-developed pseudomorph of the dolomite rhomb. The number of sides that a spherulite has is probably dependent on the number of dolomite rhombs replaced. In most of the spherulites it appears that little more than the nucleus contains the waterfilled cavities as the serrated edge of most of the spherulites is usually a clear colorless region in plain transmitted light. The arched blade, subcircular and ovate crystal fabrics are probably forms of spherulite development in various stages of formation. In these fabrics the nuclei were probably much larger, and the typical serrated outer edge is probably due to the replacement of numerous smaller dolomite rhombs surrounding the nucleus. The straight blades seen in thin section are probably remnants of large spherulites sectioned at an oblique angle, only a part of the outer surface of the spherulite being visible.

Microcrystalline granular quartz appears to be less selective in the grains it replaces and is capable of replacing a mosaic of carbonate crystals as well as dolomite rhombs.

The writer found little evidence in the thin section to indicate whether the associated anhydrite took an active or passive part in the replacement process. Rare clusters of irregularly-shaped anhydrite crystals in the silica of a few of the spherulites could be construed as an indication that the anhydrite was replaced also, and the writer has noted in one thin section that the quartz has been partially replaced by anhydrite (Plates 15 and 16, Figures 5, 6, 1 and 2 respect-

ively). Whether silica replaces anhydrite or anhydrite replaced silica seems to be dependent on the time that silicification took place.

Like many other processes which affect carbonate rocks silicification does not appear to have any fixed time of occurrence in the diagenetic sequence. Rutten (1957) and Pittman (1959) considered the silica deposits which they examined to be early diagenetic; West (1964) and Wilson (1966) noted two stages, early diagenetic and late or post diagenetic; and Biggs presented numerous valid arguments to show that the silica deposits studied by him are epigenetic.

In the writer's opinion the time of silicification can be determined from the relationship between the anhydrite and carbonate and the anhydrite and quartz. In the next section of this study (Petrology and Geochemistry of the Anhydrites, p. 121) the author will present arguments concerning the origin of the anhydrites. Suffice it to say here that the anhydrite which is found in association with the carbonate and quartz in thin section was probably formed as supratidal anhydrite in the manner described by Kinsman (1966) and therefore is early diagenetic. For the quartz to form in this carbonate-anhydrite association it would have to be deposited before the anhydrite lost its porosity, e.g., pre-lithification and probably pre-compaction. The author is of the opinion that, normally, the silica is probably early diagenetic, undoubtedly pre-lithification, and younger than the anhydrite. Exceptions to this are illustrated in the thin sections in Plates 15 and 16, Figures 5, 6, 1 and 2, respectively. In this case the quartz was formed before the anhydrite because quartz has been replaced by anhydrite. Since the anhydrite has been shown to be early diagenetic, the quartz in this example must also be early diagenetic. The time of silicification

of the carbonate strata in the interval 5708.6 feet to 5709.7 feet in the Imperial Tidewater Climax 6-10-5-18 well (Lsd. 6-10-5-18W3) was not determined due to a lack of visible criteria.

The source of the silica is enigmatic. Many workers have noted an abundance of siliceous sponge spicules within the strata containing the quartz deposits and have attributed the deposits to solution of the sponge spicules and redistribution of the silica. However, the author has not encountered any organic remains in the Saskatchewan Group which could be identified as sponge spicules and therefore has not given serious consideration to these as a source of silica in these rocks. Biggs (1957) presented the observation that, since silica is the fourth most abundant element in limestone, large quantities of it would be precipitated within the interstices of the rock and might be a significant source of silica for quartz accumulations. Whether or not the silica deposits in the Saskatchewan Group might be accounted for in this manner could not be determined.

Secondary Anhydrite Secondary anhydrite is common in the rocks of the Saskatchewan Group. It commonly occurs in two forms, metasomatic anhydrite and void-filling anhydrite. Both types are illustrated in the hand specimen in Plate 10, Figure 2. The metasomatic form consists of porphyroblastic crystals dispersed through carbonate rock. The crystals are commonly dusky yellowish brown or clear in color and when examined in thin section they are seen to be euhedral to anhedral with well developed cleavage in at least one direction (Plate 16, Figure 3). When tested for extinction direction most grains show extinction subparallel to parallel to the cleavage direction, which, according to Carozzi (1960) may be interpreted as indicating that the anhydrite is a primary

deposit. The replacement mechanism is not definitely known, rarely it is a pseudomorphic replacement but in other instances there appears to be a complete change from the carbonate crystal structure to the anhydritic crystal structure. Fossil fragments are the most common particles to be pseudomorphically replaced but the author has also noted pellets or oolites which have been partially replaced (Plate 16, Figure 5 and 6). The spherulites in Figure 5 have been replaced by bacillar anhydrite crystals having a radial orientation and enclosed by a micritic envelope. In Figure 6 the outer envelopes of the spherulites are replaced by large metasomatic anhydrite crystals surrounding a dolomite mosaic. Other spherulites in the same thin section were unaffected by anhydritization and consist of a micritic envelope surrounding a dolomite mosaic. In Figure 5 the anhydrite appears to be pseudomorphic after fibrous calcite and in Figure 6 the micritic envelope was probably replaced by a metasomatic crystal.

Anhydrite is found filling intergranular void spaces, cavities and fractures within the rocks. In Plate 10, Figure 2 it fills the cavities and fractures. Some of the cavity-filling anhydrite occurs as large blebs. In thin section, (Plate 16, Figure 4) the void-filling anhydrite consists of randomly distributed euhedral to subhedral crystals having a wide range of sizes dependent on the confining space in which they developed. The crystals have parallel to subparallel extinction, and therefore, using Carozzi's (1960) criteria, are probably primary anhydrite. Some of the crystals that infill intergranular void space may generally cover large areas, that is to say that one crystal when viewed in thin section may infill the void spaces between a large number of grains (particularly common in euhedral dolomites), present-

ing a poikilitic appearing rock.

Both of these anhydrite types are commonly found in rocks that underlie evaporitic deposits, but this is not necessarily the only situation in which they are found. They appear to be the result of precipitation of anhydrite from sulfate-rich formation waters which circulate through the more porous and permeable strata of carbonate rocks and both types seem to have appeared after lithification.

Pyrite Iron sulfide in the form of pyrite was observed in association with the carbonates, shaly rocks and evaporites of the Saskatchewan Group. It is most common in the shaly beds and in the carbonate rocks subjacent to evaporites. In the shaly beds the pyrite is in the form of cubic crystals encrusting fossil fragments, as finely disseminated crystals coating carbonate pebbles or dispersed through thin carbonate layers (Plate 7, Figure 1), and as large irregularly-shaped nodules that replace large portions of carbonate rock (Plate 3, Figure 2). When associated with carbonates and evaporites the pyrite is usually in the form of cubic crystals scattered through the rock.

The pyrite contained in the shaly beds is probably formed in a reducing environment created in the sediments by the putrefaction of the organic remains trapped in the deposit. This may be an indication that the organic remains were rapidly covered before bottom-dwelling scavenging organism were able to attack them. The pyrite associated with the evaporites and carbonates may be due to bacterial reduction of the sulfates in the interstitial waters.

Petrology and Geochemistry of the Anhydrites

Evaporites are common in the Saskatchewan Group, particularly in the Wymark and Seward Members of the Duperow Formation (Figures 12 and 15). Kent (1963, Figure 9) showed that the ratio of evaporitic rocks to carbonates is as high as 1:2 in the Wymark Member in southwestern Saskatchewan. With the exception of a few local halite deposits, notably in the Husky Phillips Eatonia No. 1 well (Lsd. 4-32-26-24W3) (Figures 6 and 12), anhydrite is the dominant evaporite.

In a previous section (see Correlations, page 75) the writer suggested that anhydrites might be useful as para-time marker beds, because they probably were deposited during a relatively short period of geologic time. Kinsman (1966) considered the recent anhydrites of the Persian Gulf to be diachronous; however, their time span is about 4000 years which when compared to the time span of the Frasnian Stage would be but an instant. However, one of the disadvantages in using anhydrites as markers beds in the subsurface, is the difficulty encountered in correlating the anhydrite bed from one well to the next. This problem arises from the fact that few anhydrite deposits have distinctive characteristics which could be used to identify them from well to well.

In anticipation that this identification problem might be solved if significant lateral and vertical trace element trends could be established for a specific anhydrite bed, the author investigated the vertical and lateral distribution of strontium (Sr) in various anhydrites of the Duperow Formation (Figure 20). In all, 353 whole rock samples (e.g., all visible lithologic components of a hand specimen were included in the powdered specimen to be analyzed) were analyzed for strontium, calcium, magnesium and potassium content, using an

Table 2

ANHYDRITE CLASSIFICATION			
Variety	Macroscopic Appearance	Microscopic Appearance	Remarks
Bedded, or banded	Dark to dusky yellowish brown or medium gray to dark gray; thin anhydrite layers separated by partings of shaly or carbonaceous material; some distorted or crenulated bedding or banding. (Plate 17, Figures 1 and 2, Plate 18, Figure 1).	Felty to bacillar with random to preferred orientation.	May be argillaceous as indicated by potassium content (see geochemical analyses - Appendix B). Scattered inclusions of dolomite.
Interlaminated dolomite and anhydrite	Alternating sequence of pale yellowish brown dolomite and dark brownish gray to dark yellowish brown anhydrite; interlaminar surfaces commonly emphasized by thin carbonaceous shale partings.	Dolomite - subhedral to anhedral grains in a mosaic of interlocking grain boundaries; euhedral dolomite crystals at carbonate-anhydrite interface; tabular anhydrite dispersed through dolomite. Anhydrite - granular to bacillar, some coarse felty; euhedral dolomite crystals porphyrotopically dispersed through anhydrite; random orientation of grains but where laminae sufficiently thin crystals may be perpendicular to underlying and overlying interfaces.	
Nodular (Chicken-wire lattice, macrocell structure)	Dark yellowish brown to dark brownish gray with grayish white dappling ("Anhydrit-perlen" - Jung and Knitzschke, 1961); lenses of anhydrite enclosed by an ubiquitous envelope of highly carbonaceous and argillaceous carbonate material. (Plate 18, Figure 2).	Felty and bacillar with some granular grains; random to preferred orient-ation; ubiquitous envelope appears as dark film generally containing dolomite rhombohedra and scattered bacillar anhydrite grains.	
Mottled (mosaic structure)	White to grayish white anhydrite with stringers and irregularly-shaped inclusions of pale yellowish brown to dark yellowish brown carbonate (Plate 19 Figures 1 and 2); the carbonate may completely or partially surround bodies of anhydrite.	Felty and bacillar with some granular grains; random to preferred orient-ation; gneissoid texture in vicinity of carbonate inclusions; micro folds associated with gneissoid texture. Dolomite stringers - anhedral to sub-hedral grains with interlocking boundaries euhedral dolomite crystals at dolomite-anhydrite interface and in a thin relict tail at the end of a stringer.	Dolomite - anhydrite interface commonly emphasized by a thin film of dark reddish brown insoluble residue.

Table 2 (cont'd)

Variety	Macroscopic Appearance	Microscopic Appearance	Remarks
Replacement	White to grayish white anhydrite with large irregularly-shaped inclusions of pale yellowish to dark yellowish brown carbonate. (Plate 17, Figure 3).	Felty to granular with patches of bacillar associated with the irregular carbonate-anhydrite interfaces; random to preferred orientation; gneissoid texture in the felty grains. Carbonate inclusions - anhedral to subhedral grains; euhedral crystals at carbonate-anhydrite interface and dispersed through anhydrite in narrow zone adjacent to the interface; tabular anhydrite porphyrotopically dispersed through the carbonate inclusions.	Thick intervals of this variety of anhydrite were observed in drill cores from the Duperow Formation (Figures 21 and 24).

x-ray fluorescence spectrometer. Before attempting a study of this magnitude, the writer investigated the feasibility of such a study by determining the distribution of strontium in 63 samples obtained from the "A" Evaporite of the Herald Member of the Upper Ordovician Red River Formation in southern Saskatchewan. (This project was done as a term research study for the 1961 postgraduate geochemistry course in the Department of Geology, University of Alberta, Edmonton.) Although the results of this investigation showed that it might be possible to correlate anhydrites on the basis of the variation in their strontium content, many questions remained unanswered. It became evident from the latter study that: 1) it would be necessary to determine next whether stratigraphically different anhydrites had different strontium distribution patterns, which could be used as a means of identification, and 2) it would be necessary also to establish whether the vertical variation in strontium content was due to precipitation factors or to diagenetic or post-diagenetic processes. In order to resolve the first difficulty, anhydrites from various stratigraphic levels in the Duperow Formation were sampled and analyzed (Figure 20). A detailed macro- and micro-petrographic study of each sampled anhydrite was done in an attempt to determine what, if any, were the effects of diagenesis on the anhydrites and their strontium content.

PETROLOGY OF THE ANHYDRITES

<u>Classification and Terminology</u> The anhydrites of the Duperow Formation may be placed into five categories as described in the accompanying table 2.

The anhydrite crystals within each of the categories are found

in various crystal habits and textures. They include:

Bacillar anhydrite - Carozzi (1960, p. 427) defined bacillar anhydrite as consisting of "mainly of narrow rods or prisms, elongated parallel to 010 which is the normal habit of anhydrite." (see Plate 20, Figure 2).

Felty anhydrite (Carozzi, 1960, p. 427) - consists of a variety of grain types with irregularly shaped boundaries. According to Carozzi the grains are ".... rod-like, spindle-shaped and rhombic individuals intergrown in a felted network ...." (Plate 20, Figure 3). In the Duperow Formation the felty anhydrites have grains covering a wide range of length to breadth ratios. The normal length to breadth ratios are between 3:1 and 12:1 but have been found as high as 17:1. These ratios are similar to those for bacillar anhydrite, but the difference between the two varieties lies in the length of the constituent crystals (bacillar ranges from 290 microns to 1.02 mm; felty from 30 microns to 312 microns) and in their appearance (bacillar-euhedral to subhedral; felty-subhedral to anhedral).

Granular anhydrite - consists of subrectangular and irregularly-shaped grains (Plate 21, Figure 1). They may constitute the entire thin section as in the illustration or may be small patches in otherwise felty anhydrite.

Tabular or lath-shaped anhydrite - large euhedral to subhedral anhydrite crystals (Plate 21, Figures 2 and 3), which appear as porphyrotopes (Friedman, 1965) in an anhydrite or in a dolomite matrix, as shown in the two illustrations. Tabular anhydrite is much broader than bacillar anhydrite and usually shows marked cleavage in at least one direction (Plate 21, Figure 3).

Gneissoid texture (Bundy, 1956) - refers to the parallel orientation of the long axes of anhydrite grains. It is well developed in felty anhydrites where the parallel orientation of the grains imparts a foliated or gneissoid appearance to the rock in thin section (Plate 21, Figures 4 and 5). Microstructures consisting of single or multiple chevron-type folds are common in gneissoid textures, and where inclusions are present in the felty anhydrite gneissoid texture a flow-like (or 'wrap-around') appearance may be produced in the vicinity of the inclusion (Plate 21, Figure 5).

<u>Association among Varieties of Anhydrite</u> A detailed study of the stratigraphy of the various categories of anhydrites indicates that nodular and mottled anhydrites are closely associated and may be interbedded with one another. Mottled and replacement anhydrite were also found to be in close association the latter generally grades into the former. In all cases this gradation was observed only in the vertical dimension but undoubtedly if close horizontal control were available lateral gradation between mottled and replacement anhydrite would also be commonly apparent.

In a succession where bedded anhydrite is present the sequence is generally nodular and mottled anhydrite overlain by bedded (Figures 22, 23 and 24). In the Tidewater Beechy Crown No. 1 well (Lsd. 1-29-23-11W3) a finer subdivision of varieties was possible and the sequence from bottom to top consists of mottled, nodular and bedded anhydrites, respectively (Figure 25). It appears, therefore, that bedded anhydrite usually marks the final product of an anhydritic phase, but it may be occasionally the initial deposit as in the Imperial Dinsmore 1-32-27-11 well (Lsd. 1-32-27-11W3) in Figures 23 and 24.

Interlaminated anhydrite and dolomite may represent a gradational contact between bedded, nodular or mottled anhydrite and the underlying or overlying carbonate strata, but it is more commonly a separate lithologic type sometimes found passing laterally into one of the other anhydrite varieties (see Interlaminated anhydrite and dolomite, Table 2).

<u>Association of Microscopic Grain Types</u> Felty anhydrite is the dominant microscopic grain type in four of the five macroscopic varieties. The exception is the interlaminated anhydrite and dolomite variety in which granular and bacillar anhydrites predominate. Bacillar anhydrite is commonly associated with the felty type, and there appears to be a gradational series from coarse felty anhydrite to bacillar anhydrite, coarse felty anhydrite being more acicular than fine felty anhydrite but more stubby than bacillar anhydrite. Carozzi (1960) considered both bacillar and felty anhydrite to be epigenetic anhydrite produced by the dehydration of gypsum. However, Kinsman (1966) noted what he considered to be primary anhydrite which consists of "a felted mass of small anhydrite laths". He found that the laths range between 2 microns and 3.8 mm. in length and have length to width ratios between 5:1 and 10:1. By comparison the grains of felty and bacillar anhydrite examined in this study are between 30 microns and 1.02 mm. in length with length to width ratios between 3:1 and 17:1. From the contrasting observations of Carozzi (1960) and Kinsman (1966) it would appear that the crystal habit of anhydrite cannot be employed as an indicator of genesis. The significance of the association of bacillar and felty anhydrite, therefore, is not obvious, but it may be that latter is in part a recrystallization product of the former. Kinsman (1966) also

noted a subparallel orientation of the laths in the anhydrites that he investigated. It was not a generally observed feature but occurred in some of the nodules. It also indicates a "wrap-around" relationship with some of the inclusions in the anhydrite. This feature is probably similar to the gneissoid texture observed in thin sections of the present study and described by Bundy (1956). Bundy found that the gneissoid texture is parallel to the bedding and concluded that it is probably the result of alignment of the grains perpendicular to compaction stresses. The writer has found that the gneissoid texture in the anhydrites of the Duperow Formation is also commonly aligned parallel to the bedding except where it appears to flow around inclusions in the anhydrite. However, because of the scattered nature of this texture, it is thought to be a primary feature similar to that described by Kinsman (1966). It may have been accentuated by later compaction and recrystallization. Granular anhydrite is commonly associated with either felty or bacillar anhydrite. It may be a primary grain habit of anhydrite or merely an "end-on" view of bacillar anhydrite. Tabular anhydrite was most often found in the carbonate inclusions in the felty and bacillar anhydrite, but was also observed in association with the other anhydrite grain habits. Where associated with the carbonate inclusions it is either a product of metasomatic replacement of the carbonate or a void-filling type of anhydrite, and where it is found within anhydrite of other grain habits, it appears to be a grain enlargement phenomenon resulting from solution producing incipient stylolites in the anhydrite (Plate 21, Figure 2).

Interpretation of Petrological and Geochemical Observations

In the writer's opinion the detailed petrology of the anhydrites may be interpreted as indicating that nodular and mottled anhydrites were formed by a mechanism similar to that described by Whithington (1961), Kerr and Thompson (1963) and Kinsman (1966). They all suggest that nodular calcium sulfate deposits are the result of interstitial precipitation of calcium sulfate in carbonate or clastic (mainly clayey) sediments. Kerr and Thompson (1963) found bladed crystals and rosettes of gypsum forming in the sediments below the Laguna Madre on the south coast of Texas. They compared these recent gypsum deposits to ancient anhydrites from the Permian of West Texas and New Mexico, and attributed their origin to precipitation from interstitial waters supersaturated with respect to gypsum by the downward percolation of hypersaline lagoonal waters. Kinsman (1966) found nodular anhydrite forming in the carbonate sediments of a supratidal coastal plain along the Trucial Coast in the Persian Gulf region. The environments in this area from seaward to landward consist of; coral reef or oolite delta, tidal channel, inner fringing reef and island, lagoon, algal flat, and salt flat or sabkha. The sabkha is formed by the slow infilling of the lagoon by carbonate deposits. The material infilling the lagoons is dependent on the shelter provided, where the lagoons are well-sheltered fine-grained sediments are common; in the less-sheltered areas the materials are largely skeletal sands and gravels. Kinsman (1966) observed that the ground water depth in the sabkha sediments is between 1 and 4 feet below surface and approximately at sea level. Above this is a zone of continuous capillary pore water. Evaporation losses from the sabkha surface causes marine lagoonal waters to enter the sediments.

The evaporation results in an increase of salinity and chlorinity in the interstitial waters upward and landward. He found that gypsum is deposited in the sediments on the lagoonal side of the *sabkha* and anhydrite in the inner *sabkha* where the chlorinity of the ground water reaches 130 o/oo and the sulfate concentration decreases to 20 percent. Since 20 percent sulfate concentration is insufficient to produce extensive anhydrite deposits Kinsman suggested that some of the gypsum was dissolved to provide the required amounts of sulfate. The precipitation and development of nodular anhydrite in the *sabkha* sediments occurs while the sediments are plastic and consequently easily deformed and displaced.

In the anhydrites of the Duperow Formation, the nodular anhydrite appears to have been formed in extremely fine-grained, highly organic sediments and the mottled anhydrite appears to have developed in coarser-grained carbonates. In the latter variety portions of the carbonate material may have been replaced by the anhydrite, resulting in the replacement variety. The time of replacement is not clear but it seems probable that it was during diagenesis, since in the writer's opinion it would have occurred at a time when sulfate-rich solutions were able to circulate through the sediments, e.g., before the interstitially-deposited anhydrites lost their primary porosity.

Kinsman (1966) observed that the recent supratidal anhydrites of the Trucial Coast are not banded or laminated, but both types have been found associated with the nodular and mottled anhydrites of the Duperow Formation. The stratigraphic position of the bedded or banded variety of anhydrite in these ancient deposits suggests a late phase of anhydrite sedimentation possibly by precipitation from marine waters

which may have occasionally flooded the supratidal region. The usually high argillaceous content of this anhydrite type suggests that the water from which the precipitate originated was highly turbid, which might be the case if a supratidal flat was flooded.

Interlaminated dolomite and anhydrite of the Saskatchewan Group are probably supratidal flood plain deposits also. When interlaminated dolomite and anhydrite occurs at the top of a succession of nodular or mottled anhydrite, it probably represents the last phase of anhydrite sedimentation. Interlaminated dolomite and anhydrite at the base of mottled or nodular anhydrite was probably formed much earlier than the carbonates in which the interstitial anhydrites were deposited. After burial by supratidal deposits and the precipitation of calcium sulfate the interlaminated deposits would form a barrier against further interstitial deposition and consequently form an apparently gradational contact between the overlying mottled anhydrite and the subjacent carbonates.

The mean strontium concentrations for the various categories of anhydrite are comparable to those for other anhydrite deposits which have been described in the literature. For example, Herrmann (1961) studied the strontium concentration of the Stassfurt series of the Permain Zechstein deposits in the Southern Harz District. He found that the basal anhydrite and underlying dolomite are the only strata to contain only isomorphous strontium in the anhydrite lattice; all others contain both isomorphous strontium and celestite, giving extremely high strontium values. The basal anhydrite contains an average of 1336 ppm Sr. Another study (Muller, 1964) included anhydrite samples from the Permian Zechstein and the Triassic Muschelkalk of West Germany contain-

ing average strontium values of 1049, 1110, 1185, and 1200 ppm. Muller also found that the anhydrites having q values between 3 and 7 contained only isomorphous strontium.

Jung and Knitzschke (1961) carried out a detailed investigation of a number of anhydrites from the Permian Zechstein of the southeast foreland of the Harz Mountains. These anhydrites were intersected in a number of boreholes, and were found to consist of a variety of petrographic types, some of which, from their descriptions, appear to be similar to the categories outlined in this study. The lowest anhydrite examined in each well was divided into three varieties with strontium concentrations between 2500 ppm and 8500 ppm and q values between 5.6 and 12.3. Employing Muller's (1964) q value limits it would appear that some of the basal anhydrites of Jung and Knitzschke's (1961) study contain celestite. On the other hand, the main anhydrite, in which they outlined six categories of anhydrite, have strontium values comparable to those recorded for the anhydrites of the Duperow Formation, and range between 700 and 1700 ppm Sr. The zone which consistently has the highest strontium concentrations (1100-1600 ppm Sr) was described as being composed of banded anhydrite containing some stringers of argillaceous dolomite. This variety appears to be similar petrologically and geochemically to the bedded anhydrites of the present study (Table 2).

In contrast to the comparable strontium values for ancient anhydrites as listed in the previous paragraphs, Braitsch (1962) recorded a strontium concentration of 2800 ppm for the gypsum deposits of the Upper Miocene Sulphur Series of Sicily, and a similar value for recent gypsum from Lake Inder. These concentrations are much higher than the strontium concentrations of recent gypsum from the Persian Gulf as

recorded by Kinsman (1964). He found these gypsum deposits to contain an average of 800 ppm Sr. Recent anhydrites from the same region have as much as 2200 ppm Sr. In a personal communication Kinsman advised the writer that the recent gypsum ranges between 700 and 900 ppm Sr. and the recent anhydrite varies from 1900 to 2200 ppm Sr. These values appear to be more consistent with other studies which have found ancient gypsum to contain less strontium than anhydrite; for example, Ham (1962) found that the gypsum deposits of Oklahoma contain an average of 970 ppm Sr. and the anhydrites 1475 ppm Sr. Kropachev (1960) noted higher strontium concentrations for gypsum than anhydrite, but on the other hand attributed the increase in strontium in the gypsum to precipitation from groundwater with a high strontium content.

When the geochemical portion of this study was begun the writer was hopeful that, among other things, the strontium concentration of an ancient anhydrite could be employed to determine whether the anhydrite was a primary deposit or secondary after gypsum (the latter was expected to have low strontium values). But the inconsistencies in the maximum amount of isomorphous strontium that gypsum can contain, presents some doubt concerning the validity of this hypothesis. However, in the opinion of the author, where an ancient anhydrite can be correlated with a recent deposit as regards petrology and geochemistry, as in the case of the anhydrites of the Duperow Formation and the recent deposits of the Persian Gulf, the strontium content, in fact, does become a significant indicator of primary or secondary anhydrite. Undoubtedly, diagenetic and post-burial recrystallization of ancient anhydrite deposits has resulted in the loss of some strontium, just as it has in carbonates (Turekian, 1964). Thus many of the strontium values

between 900 ppm and 1900 ppm in the anhydrites of the Duperow Formation are probably lower than the strontium concentrations of the recent anhydrites because of recrystallization. However, a large number of the low values in this range are from mottled and replacement anhydrite and consequently have a high carbonate content which may cause dilution of the strontium concentration. Those values below 900 ppm Sr may be from samples that were close to an original anhydrite-gypsum interface, the gypsum having been inverted to anhydrite at depth.

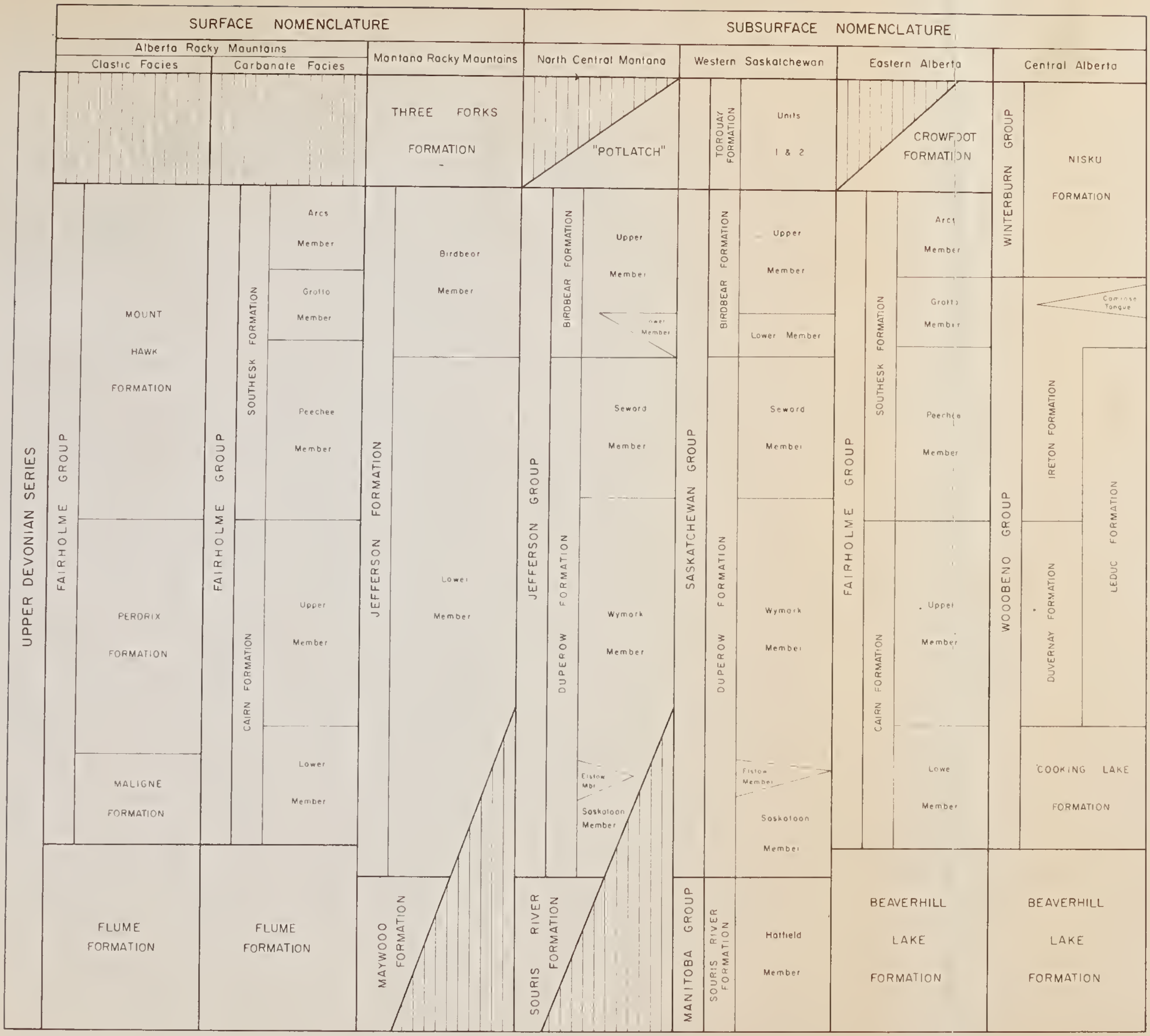
The geochemical profiles (Figures 21 to 25 inclusive) show that there is a variation in the strontium concentration over the vertical thickness of an anhydrite bed. Although recrystallization has probably had the affect of an overall lowering of the strontium concentration of an anhydrite, the various maxima and minima on the strontium curves probably reflect amounts of strontium available at the time of deposition. There does not appear to be any specific pattern of strontium concentration distribution which can be applied to a particular anhydrite bed and identification of an anhydrite purely by its strontium content does not appear to be possible.

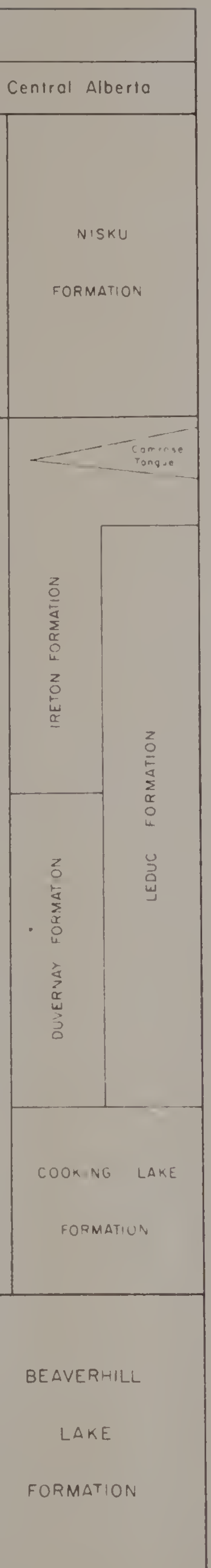
The writer is of the opinion that if the distributions of other trace elements are investigated in conjunction with the distribution of strontium, it may then be possible to identify an anhydrite by means of its trace element content.

Sedimentary Framework

The rocks of the Saskatchewan Group and its lateral equivalents demonstrate both regional and microfacies relationships within the study area. The regional facies are defined on the gross lithologic

Table I


SURFACE NOMENCLATURE
SUBSURFACE NOMENCLATURE
Alberta Rocky Mountains
Clastic Facies
Carbonate Facies
Montana Rocky Mountains
North Central Montana
Western Saskatchewan
Eastern Alberta
Central Alberta
UPPER DEVONIAN SERIES
FAIRHOLME GROUP
MOUNT HAWK FORMATION
PERDRIX FORMATION
MALIGNE FORMATION
FLUME FORMATION
FAIRHOLME GROUP
SOUTHESK FORMATION
Arcs Member
Grotto Member
Peechee Member
CAIRN FORMATION
Upper Member
Lower Member
FLUME FORMATION
THREE FORKS FORMATION
JEFFERSON FORMATION
Birdbear Member
Lower Member
MAYWOOD FORMATION
"POTLATCH"
JEFFERSON GROUP
BIRDBEAR FORMATION
Upper Member
Lower Member
DUPEROW FORMATION
Seward Member
Wymark Member
Elstow Mbr
Saskatoon Member
SOURIS RIVER FORMATION
TORQUAY FORMATION
Units 1 & 2
SASKATCHEWAN GROUP
BIRDBEAR FORMATION
Upper Member
Lower Member
DUPEROW FORMATION
Seward Member
Wymark Member
Elstow Member
Saskatoon Member
MANITOBA GROUP
SOURIS RIVER FORMATION
Hatfield Member
CROWFOOT FORMATION
FAIRHOLME GROUP
SOUTHESK FORMATION
Arcs Member
Grotto Member
Peechee Member
CAIRN FORMATION
Upper Member
Lower Member
BEAVERHILL LAKE FORMATION
WINTERBURN GROUP
NISKU FORMATION
Camrose Tongue
WOODBEND GROUP
IRETON FORMATION
LEDUC FORMATION
DUVERNAY FORMATION
COOKING LAKE FORMATION
BEAVERHILL LAKE FORMATION



Central Alberta
NISKU FORMATION
Camrose Tongue
IRETON FORMATION
LEDUC FORMATION
DUVERNAY FORMATION
COOKING LAKE FORMATION
BEAVERHILL LAKE FORMATION

characteristics of the rocks, i.e., fine clastic rocks, carbonate rocks, or evaporitic rocks. Microfacies, for example organic carbonate facies and pellet carbonate facies, occur within a particular regional facies.

REGIONAL FACIES

The Saskatchewan Group and its lateral equivalents display three regional facies, including carbonate, fine-clastic (composed of interbedded highly argillaceous carbonates, calcareous shales and marlstones), and evaporitic (including anhydrite and halite). These have been discussed in some detail under "Detailed Stratigraphy" (p. 20) and their distribution alone is considered here with a view to determining the source of the materials which constitute the rocks. Various accompanying cross-sections and panel diagrams (Figures 3,4,5,6,7,8,9,12 and 15) show that the most common change in regional facies occurs between the fine-clastic lithologies and the carbonate lithologies. They also show that these changes occur in each stratigraphic unit of the Saskatchewan Group, but not collinearly.

The carbonate to fine-clastic change in the Saskatoon Member occurs along a line which trends in a northeasterly direction from the southwest corner of western Saskatchewan (Figure 11). The fine-clastic rocks are on the western side of this line and when traced further westward become the uppermost beds of the Beaverhill Lake Formation. The distribution of this fine-clastic facies and the overall increase in the argillaceous content of the Beaverhill Lake Formation in a northwesterly direction(Alberta Society of Petroleum Geologists Committee on Slave Point and Beaverhill Lake Formation, 1964) may be interpreted as an indication that the source of the fine-clastic sediments was from

that direction.

The Elstow Member over most of the area of study is composed of argillaceous materials. The member loses its identity where it changes facies to non-argillaceous carbonates along an irregular line which extends across north central Montana (Figure 11), turns sharply north just east of the map area, and north of the International boundary trends northeasterly across eastern Saskatchewan. The distribution of the Elstow Member and its lateral equivalents in the Cairn Formation of eastern Alberta and the Cooking Lake Formation of central Alberta (Figures 3,4,5,6,8 and 12) suggests a northeasterly source for the fine-clastic materials.

The Wymark Member is most significant because the main carbonate to evaporite facies changes occur within it, particularly in the central portion of western Saskatchewan, where there are numerous anhydrites interbedded with the carbonate rocks. These anhydrites commonly pass laterally into carbonates toward the edges of the map area. The thickest evaporitic deposits in the region consist of halites and anhydrites (Figure 12) which grade laterally into carbonates of various microfacies. Along the northeast side of the map area the middle and upper units of the Wymark Member change facies to fine-clastic lithologies (Figure 8). It is not possible to outline the distribution of these fine-clastic rocks because most of them have been removed by erosion, but the change in the subcrop pattern of the Wymark Member (Figure 2) on the northeast side of the map area suggests that the more easily eroded fine-clastic materials encroach into the area of study from the northeast, and therefore that the source of these sediments was from that direction.

The argillaceous strata of the Seward Member are found over most of the region of study. They change facies in the west along the arbitrary cut-off (Figures 3,4,5,6,14 and 15), but they extended at least as far as the southern limits of the map area and have been traced to the southeast into the State of North Dakota (Figure 6). It would appear, therefore, that the source of the fine-clastics in this unit was also to the northeast. The distribution of fine-clastic sediments in the lower and upper members of the Birdbear Formation (Figures 17 and 18) also indicate a northeasterly source.

The source directions of the fine-clastic sediments of these stratigraphic units is consistent with the observations of Oliver and Cowper (1963) who presented evidence that the shaly materials of the Ireton Formation east of the Rimbey-Meadowbrook reef chain were from the east, that is, from a land area somewhere in Saskatchewan.

MICROFACIES

The best defined microfacies in the regional facies of the Saskatchewan Group are those of the carbonate strata of the Saskatoon and Wymark Members of the Duperow Formation and the Birdbear Formation. There are three significant microfacies in the carbonates of these units:

1) Organic facies,
2) Non-skeletal sand facies,
3) Microcrystalline carbonate ooze facies.

<u>Organic Facies</u> Rocks of this facies include organically constructed deposits produced by stromatoporoids, bryozoa, corals and algae, and calcarenites or calcirudites of fragmented and whole fossil remains. The latter are commonly composed of shell remains of brachiopods, gastropods,

and bryozoa and of crinoid columnals. The fossil fragments are seldom packed sufficiently close together to form the framework of the rock, and the interstices are commonly infilled by microcrystalline carbonate ooze (micrite).

Algae are the dominant rock-building organisms and were observed in layered sequences similar to the type illustrated in Plate 11, Figure 1, as stromatolites or concentric singular growths similar to types described by Logan _et al_. (1964). The concentric singular growths may be attached to older carbonate strata (Plate 11, Figure 2) or in the form of nodules.

Non-skeletal Sand Facies The term non-skeletal sand was employed by Illing (1954) to describe the oolitic, pelletoid and 'lump' deposits on the Bahama Banks. The writer uses the expression in the same manner because it is difficult to distinguish between pellets, oolites and pseudo-oolites in hand specimens. The constituent particles are ovoid to spherical in shape and range between 0.0625 mm. and 1.67 mm., the average being about 0.3 mm. Pellets composed of micritic material predominate, but composite particles containing a number of pellets cemented together and enclosed by a thin envelope of calcitic material are also present. These may be similar to some of the particles called intraclasts by Folk (1959, 1962). Oolites were not positively identified in any of the thin sections examined, but particles which may have been oolites later replaced by anhydrite and dolomite were described in a preceding section (see Secondary anhydrite, p. 113, and Plate 16, Figures 5 and 6).

The particles commonly constitute a self-supporting framework having grain to grain contact within the rock and are generally cemented

by sparry calcite. However, the pellets also may be abundantly dispersed throughout a micritic matrix without pellet to pellet contact. Because of the manner in which information is obtained concerning the various facies in the Saskatchewan Group (that is to say, from cores and well cuttings), it is difficult to determine whether any major sedimentary structures are present. However, the core that is illustrated in Plate 11, Figure 2 does show a feature which might be interpreted as cross bedding in a pelletoidal lithology. This may be an indication that at least some portions of the non-skeletal sand deposits of this group have been agitated by wave action and formed into banks or dunes.

Microcrystalline Carbonate Ooze Facies It was pointed out in an earlier section (Diagenesis of the Carbonate Rocks, p. 95) that the microcrystalline carbonate ooze is the most common lithologic type present in the rocks of the Saskatchewan Group. The rocks are composed of calcite grains which commonly range between 5 and 15 microns (previously shown to be a recrystallized product of micrite - recrystallization p. 96). The rock is probably highly susceptible to dolomitization, and a large portion of the dolomitized rocks of the group were originally micrite. The grain size in the dolomitized rocks ranges between 40 and 80 microns. The dolomitized equivalents are most often found associated with the regions of thick and numerous anhydrite beds (Figures 12 and 15).

Fossils (brachiopods, gastropods, ostracods, bryozoa and some crinoid columnals) are present in the strata of the microcrystalline carbonate ooze facies, but are not plentiful. The state of preservation of the fossils varies with the degree of dolomitization. Observations in thin section indicate that the fossil remains were the last

calcitic or aragonitic material to be dolomitized.

Fine-Clastic Deposits and Evaporites There are within the fine-clastic and evaporite deposits some variations in microfacies. The extent of many of these cannot be outlined because of insufficient well control. However some are of a more regional character and it is these that are considered here.

Subunit B3 of the Seward Member is generally composed of reddish brown, highly argillaceous dolomites and dolomitic shales but grades laterally into greenish gray to grayish green calcareous shales and olive gray to medium gray very argillaceous limestones. Another facies change occurs in the lower member of the Birdbear Formation where the greenish gray and grayish green calcareous shales and marlstones and the gray argillaceous limestones pass laterally into greenish gray marly siltstones and silty shales.

Changes of facies in the evaporite deposits are not common in the Saskatchewan Group. Lateral gradation from anhydrite to halite can be shown to occur only in west-central Saskatchewan (Figure 12).

DISTRIBUTION OF MICROFACIES

Observations presented here concerning the distribution of the microfacies within the rocks of the Saskatchewan Group can only be broad approximations, since the well-control in the region of study does not lend itself to any detailed microfacies analysis.

Saskatoon Member The carbonate rocks of the Saskatoon Member exhibit all three carbonate microfacies discussed in the previous paragraphs. the microcrystalline carbonate ooze facies predominates in the southwest corner of western Saskatchewan and in the southwest corner of eastern Alberta (see Figure 12). Rocks of this facies extend southeasterly

in to Montana as far as the northern edge of the central Montana uplift, and northward in a narrow strip along the Alberta-Saskatchewan inter-provincial boundary. In the east and west the microcrystalline carbonate ooze facies is flanked by non-skeletal sands and in the north by strata of organic facies which extend across central western Saskatchewan. A tongue of rocks of the organic facies also extends westward into the micro-crystalline ooze along the International border (Figure 12).

<u>Wymark Member</u> Rocks of the organic facies constitute the major portion of the lower unit of the Wymark Member in western Saskatchewan, and microcrystalline ooze is the dominant lithology in eastern Alberta and north-central Montana.

In the middle unit of the Wymark Member, numerous and commonly thick evaporite deposits occupy a broad portion of western Saskatchewan and eastern Alberta mainly between the 50th and the 52nd meridians of latitude (Figure 12). Microcrystalline ooze sediments are commonly associated with the evaporites. This interbedded sequence of evaporites and microcrystalline carbonates is flanked on the east by non-skeletal sands and on the north and west by rocks of the organic facies. Carbonate ooze extends southward into Montana.

During deposition of the upper unit of the Wymark Member, the area of maximum evaporite accumulation migrated farther east and is actually beyond the eastern boundary of the map area, but for the most part the upper unit is predominantly composed of evaporites and associated microcrystalline ooze (Figure 12).

When traced to the northwest the rocks of the Wymark Member and its lateral equivalents (Figure 12) pass laterally into the southern

Alberta Marginal Reef Complex, which is marked by a thick sequence of rhombic dolomite.

Birdbear Formation Although highly dolomitized over much of the area, which makes it difficult to identify any original carbonate microfacies, in the author's opinion the Birdbear Formation mainly consists of microcrystalline ooze. However, a highly dolomitized organic or non-skeletal sand extends over much of central western Saskatchewan. This is represented in part by a thick rhombic dolomite accumulation (Figure 15).

Other Units The red bed deposits of subunit B3 of the Seward Member are found in the eastern part of western Saskatchewan, and they extend in a somewhat irregular manner as far south as the Beartooth uplift where they have been located in an outcrop of Jefferson Formation in Boulder River Canyon southeast of Livingston, Montana. These red beds change facies to the west and northwest as described in previous paragraphs (Figure 15). A similar facies change occurs toward the east.

The previously described silty facies of the lower member of the Birdbear Formation is found in the vicinity of Saskatoon, but north and east of that area the Birdbear Formation is absent due to erosion.

Tectonic Framework

The isopach map of the interval between the top of the lower member of the Birdbear Formation and the top of the Souris River Formation (Lower Birdbear-Duperow interval) (Figure 28) shows that the axis of maximum sedimentation for the rocks of this interval has a west-northwest east-southeast trend across the map area between the 51st and 52nd meridians of latitude. The axis plunges to the northwest suggest-

ing that the region of study was tilted in that direction and subsided somewhat more rapidly in the northwestern part of this area, during Late Devonian time.

Isopach maps of the various stratigraphic units of the Duperow Formation (Figures 11, 13 and 14) show that there is a gradual south-westerly shift of the axes of sedimentation with each successively younger unit. But in each unit the axis has a similar northwest-south-east trend. Figures 11, 13, 14 and 28 show a general south-southwest-erly and north-northeasterly thinning of the members of the Duperow Formation. A locally developed depositional limit of the Saskatoon and Elstow Members occurs in western Montana in the region of a structural element described as the Genou Trend (Alpha, 1955a) but in most other units the depositional limits are either beyond the map area or are in-determinate because of facies change necessitating the introduction of arbitrary cut-off lines to delimit the areas where the units are not identifiable. For example, the lower strata of the Duperow Formation (Saskatoon-Elstow equivalents) dwindle to a depositional limit south of the arbitrary cut-off in Montana, in the vicinity of the Little Rocky Mountains (Figures 2, 11 and 12). The positive element that this edge outlines was probably the northern tip of the central Montana uplift, which appears to have been a northwesterly trending peninsula of the Transcontinental Arch landmass during early Late Devonian time (Kent, 1964a). The thinning of the Wymark Member in the same area indicates that this feature was a positive element during part of the time that the sediments of this member were being laid down. However, the de-positional limits of both the Wymark and Seward Members are beyond the limits of the map area.

The regional depositional strike and axis of maximum sedimentation of the lower member of the Birdbear Formation is oblique to the depositional strikes and axes of sedimentation of the underlying strata (Figure 17). The sediments of this unit appear to have been deposited in a slowly subsiding trough centred in central western Saskatchewan. The member thins in all directions from this region, and is locally absent over the southern Alberta Marginal Reef Complex. A regional depositional limit for the unit has not been mapped since it changes facies to the south, southwest and east, it has been eroded in the north and northeast and it merges with the Ireton Formation in the west.

It is difficult to perceive a tectonic pattern for the sediments of the upper member of the Birdbear Formation because of the variation in thickness of the unit over much of the area. However, it appears that most of the map area was tilting toward the northwest at the time that the sediments of this unit were being deposited.

There are a number of subparallel northwest-southeast trends of anomalously thick strata which interrupt the regional thickness trends of the isopach maps of the various units of the Duperow Formation (Figures 11, 13 and 14). These anomalies are also reflected in the isopach map of the lower Birdbear-Duperow interval. The trend and location of the anomalies overlying the "salt free" area, but in close proximity to the present edge of the Prairie Evaporite Formation, may be interpreted as indicating that these anomalies are the result of late Middle Devonian to early Late Devonian salt removal and subsequent subsidence during the time that the sediments of the Duperow Formation were being deposited.

DEPOSITIONAL ENVIRONMENTS

Consideration of the distribution of the lithologies within the stratigraphic units of the Saskatchewan Group in the light of the isopach trends discussed in the preceding paragraphs assists in the interpretation of the depositional history of the region of study.

The preponderance of micritic material, both as a separate lithology and as the matrix in the organic facies, suggests that most of the region was protected from excessive wave action. However, along the eastern side of the map area, where non-skeletal sands are the dominant lithology in both the Saskatoon and Wymark Members, some current or wave action must have been effective. Since the non-skeletal sands are primarily composed of pellets the area was probably one with a bottom stabilized by Devonian algal analogs of modern marine grasses but current action was effective enough to have winnowed most of the micrite from the interstices of the pelletoid sediments. The area of somewhat more rapid subsidence associated with the axis of maximum sedimentation for the Saskatoon and Elstow Members is the region where the thickest portions of the fine-clastic facies of the Saskatoon Member are present. In the Wymark Member the organic facies is aligned with the depositional strike, particularly on the northern side of the axis of maximum sedimentation, but microcrystalline ooze interbedded with anhydrites predominates in the area of more rapid subsidence associated with this axis. The thick anhydrite-halite sequence found in the Wymark Member also occurs in the vicinity of the axis of maximum sedimentation. The euhedral dolomite accumulation northwest (Figure 12) of this halite-anhydrite sequence is a dolomite rim at the periphery of the evaporitic deposits and may represent a low reef which acted as a barrier to circulation

during part of the time the sediments of the middle unit of the Wymark Member were deposited. The evaporites along the axis of maximum sedimentation, therefore, were most likely restricted-basin deposits. However, the anhydrites to the north and south of the axis appear to be supratidal deposits formed in part in the interstices of the carbonate sediments (see Petrology and Geochemistry of the Anhydrites, pp. 121). If this is a valid interpretation of the environment, then it suggests that the region underwent several short stages of subsidence and stillstand. The stillstand resulted in regression of the marine waters from the region accompanied by the formation of supratidal anhydrite deposits. The supratidal anhydrites are more numerous and widespread in the upper unit than in the middle unit of the Wymark Member indicating that a larger portion of the region was undergoing shorter periods of subsidence at this time.

Supratidal anhydrites are also present in unit A of the Seward Member, particularly in the area north and east of the axis of sedimentation. The rocks in the more rapidly subsiding region along the axis are mainly composed of organic and non-skeletal deposits. The large proportion of fine-clastic material in the Seward Member of the Duperow Formation and the lower member of the Birdbear Formation probably reflects an increase in the elevation of the peripheral landmasses. The red beds at the top of the Seward Member in the eastern portion of the map area suggest that that region was above sea level and subjected to weathering and erosion. The uplift appears to have been extensive since red beds at the same stratigraphic position have been found as far away as the Boulder River Canyon, southeast of Livingston, Montana.

The sediments of the upper member of the Birdbear Formation

may be interpreted as having been deposited on a relatively stable platform free from excessive wave or current action.

GEOLOGICAL HISTORY

A portion of the cratonic interior of North America, the area of study underwent two major stages of subsidence and three stages of emergence marked by interregional unconformities during post-Precambrian to pre-Middle Devonian times. The last period of emergence during this interval occurred during a post-Upper Silurian pre-Middle Devonian period (pre-Kaskaskia unconformity of Sloss, 1963). This pre-Kaskaskia unconformity was developed on progressively younger Lower Paleozoic rocks in the area, beginning in the west with Cambrian rocks through to Silurian strata at the eastern boundary. In the southern portion of the map area the unconformity spans an even greater time gap as no sediments were deposited on the eroded Lower Palaeozoic rocks until early Late Devonian times. Thus during Middle Devonian (Eifelian and Givetian) times the northern part of the study area was occupied by a northwest-southeast trending basin which was flanked on three sides by land areas and was open to the northwest (Kent, 1964a). The southern land area included southwestern Saskatchewan, southeastern Alberta and north central Montana.

The sedimentological history of the basin is marked by several stages of subsidence, stillstand (accompanied by regression of the sea) and emergence. The subsidence and stillstand stages are represented by carbonate and evaporite deposits and the emergence stage is exemplified by reddish and greenish dolomitic shale and shaly dolomite beds. During each successive subsidence stage progressively more of the land area on the south side of the basin was inundated. This was accompanied by a gradual southward shift of the position of the axis of the basin and a change to a more westerly trend (Kent, 1967).

By earliest Late Devonian time (early Frasnian) all of southwestern Saskatchewan and southeastern Alberta and most of north central Montana were covered by a shallow shelf sea (the exceptions being the central Montana uplift and the Genou Trend - Kent, 1964a). The fine-clastic sediments that predominate in some of the early Frasnian strata (Harris and Hatfield Members of the Souris River Formation, and Saskatoon and Elstow Members of the Duperow Formation) probably reflect epeirogenic fluctuations of the surrounding land areas especially those to the north which appear to have been the source for these sediments. In the writer's opinion the flat-pebble conglomerates (pp. 89 - 91) in these fine-clastic sediments indicate that the sea was shallow over the area and that some localities may have been above sea level for short periods during the time these sediments were deposited.

The tectonic movements which caused the epeirogenic fluctuation of the land areas appears to have activated linear structural elements in central Alberta producing upwarped areas of the sea floor which were focal points for organic reef growth. Activated structural elements in western Saskatchewan may have been the focal points for the removal of Givetian salt deposits resulting in local subsidence during middle Frasnian time (pp. 260-263). During the period of reef growth a shallow shelf sea covered most of the map area. The various carbonate microfacies (pp. 129-132) deposited in the shelf environment may be interpreted as indicating that the region seldom underwent excessive agitation by moving waters. The region of reef growth appears to have been subsiding more rapidly than the shelf region. This is probably because the shelf region appears to have undergone periods of subsidence when the carbonate microfacies were deposited, followed by

periods of stillstand when portions of the area were supratidal flats where anhydrite deposits were developing. Other portions of the shelf during the stillstand stages were probably restricted basins in which anhydrite and halite were deposited. Shallow shelf carbonate sedimentation continued until late Middle Frasnian times at which time fine-clastic sediments probably from the northeast again spread over much of the region. Reef growth continued in central Alberta at this time.

Sedimentation in the eastern and southeastern portions of the study area was interrupted by uplift at two different stages of late Middle Frasnian time. The earlier is reflected in the reddish and greenish beds which mark the top of the Duperow Formation. The land area that resulted from this emergence appears to have been on the northern flanks of an uplift centred in the vicinity of the Big Snowy Mountains (Figure 2) in central Montana. This land mass was probably one of relatively low relief, but may have supplied some of the fine-clastic sediments found in the lower member of the Birdbear Formation or its equivalent in eastern Alberta. With gradual inundation of the land area by a transgressing sea from the west, much of the residual soil of the land mass was probably reworked and oxidized producing the greenish-gray and grayish-green hues which predominate in the beds at the top of the Duperow Formation. Reddish brown sediments are most commonly encountered only in the region nearest the eastern boundary of the map area, which was probably the last part of the land mass to be inundated. Shelf carbonate sedimentation was again initiated over the study area upon complete inundation of the land area. However, it was again interrupted by the second emergence of the area during late Middle Frasnian time. During the period of carbonate shelf sedimentation,

reef growth in central Alberta was halted, probably by an ever-increasing influx of fine-clastic materials into that area from the north and northeast. The uplift which interrupted carbonate sedimentation appears to have been earliest in the eastern part of the map area and to have extended slowly westward until most of the northern Great Plains area was above sea level. The uplift at the end of Frasnian sedimentation in the map area is marked by the widespread regolith in unit 2 of the Torquay Formation (Christopher, 1961), by the erosional surface on the top of the Birdbear equivalent in eastern Alberta and by the red beds of the Crowfoot and Graminia Formations of central Alberta (Figure 16). While the eastern part of the study area was emergent evaporitic deposits were being laid down in the west, as represented by the Crowfoot Formation and the upper part of the Nisku Formation. The carbonate rocks that were exposed during this emergent period were deeply weathered leaving units 1 and 2 of the Torquay Formation as the residue.

During early Fammenian time western Saskatchewan was near sea level with the result that slight fluctuations of the level of the sea caused inundation or emergence of the land area. Emergence was accompanied by weathering of the sediments deposited during submergence (Kent, 1964a). The late stages of sedimentation during Fammenian time are represented by sediments deposited during two subsidence stages and interrupted by an emergent stage. The first subsidence stage is represented by the deposits of the Big Valley Formation which upon emergence were deeply eroded (Christopher, 1961 and Kent, 1967). The second subsidence is represented by the lower black shales of the Bakken Formation. The latter appear to be the youngest Devonian strata present in the region of study.

SUMMARY AND CONCLUSIONS

The combination of macrofossils, microfossils (sporomorphs) and para-time marker horizons indicate that the Saskatchewan, Fairholme, Woodbend and Jefferson Groups are time-stratigraphic equivalents. The facies changes among these groups may be delineated by arbitrary cut-off lines which represent the lines across which the major lithologic characteristics of the groups are no longer easily recognized.

The sediments of the Saskatchewan, Fairholme and Jefferson Groups of the region of study were deposited in shallow water covering a broad shelf area. The shelf area underwent repeated subsidence and stillstand. Periods of subsidence are represented by the carbonate and fine-clastic lithologies and stages of stillstand by supratidal anhydrites. Two regional unconformities, one within the Saskatchewan Group and the other at or near the top of the Saskatchewan, Jefferson and Fairholme Groups, represent important periods of uplift in the study area. The latter erosional stage had the effect of producing a thick weathered residue on the top of the carbonate strata of the Birdbear Formation in many parts of the map area and in particular in western Saskatchewan.

In conclusion the author is of the opinion that the information presented in this thesis indicates that the Birdbear Formation and the Nisku Formation overlap in a time-stratigraphic sense. That is to say, the uppermost beds of the Birdbear Formation are probably time correlatives of the lower strata of the Nisku Formation. While the sediments that represent the upper beds of the Nisku Formation were being deposited in central Alberta, the region farther east was under-

going weathering and erosion, producing a weathered residue represented by units 1 and 2 of the Torquay Formation (Christopher, 1961) overlying the Birdbear Formation. Although the Birdbear and Nisku may be regarded in some respects as lithologically similar, in the author's opinion the use of the name "Nisku" for the interval now described as Birdbear can continue only in defiance of the evidence presented by the rocks themselves.

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APPENDIX A

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Formation and Member Tops determined from Cores, Samples and Well Logs.

ABBREVIATIONS AND SYMBOLS EMPLOYED IN WELL LISTS

Alb.	Albercan
Anglo. Amer.	Anglo American
B. A.	British American
Calstan	California Standard
Cal.	Calvan
C. S.	Community Service
Canso	Canada Southern
Can. Dev.	Canadian Devonian
Cdn. Exp.	Canadian Exploration
Cdn. Seab.	Canadian Seaboard
C. D. R.	Central Del Rio
Col.	Coleman
C. M. and S.	Consolidated Mining and Smelting
Cont. Pot.	Continental Potash
D. H. P.	Delhi-Husky-Phillips
D. S. P.	Duval Sulfur and Potash
Fed. Co-op.	Federated Co-operative
F. S.	Freeport Sulfur
G. P.	General Petroleum
Grt. Plns.	Great Plains
G. T. W.	Gulf-Tidewater
H. N. B.	Herschel North Battleford Syndicate
Hstd.	Homestead
H. B.	Hudson Bay

H. J.	Husky-Jupiter
H. P.	Husky-Phillips
Imp.	Imperial
Int.	International
Lib.	Liberal
McC	McCarty
M. O.	Mobil Oil
M. O. W. S.	Mobil Oil - Woodley - Sinclair
N. P.	National Potash
Nuco	Nufield Operators Ltd.
Pan Am	Panamerican
P. H.	Phillips-Husky
P. C. A.	Potash Company of America
Rich.	Richfield
Roy.	Royalite
R. G. A.	Royalite General American
Soc.	Socony
S. M. U. S.	Socony Mobil-Union-Sinclair
S. W. P.	Socony-Western Prairie
S. W. S.	Socony-Woodley-Sinclair
Som.	Somerset
Sup.	Superior
T. P.C. & O	Texas Pacific Coal and Oil Co.
T. W.	Tidewater
U. S. B. and C.	United States Borax and Chemical
U. S. P.	United States Potash
W. R.	White Rose

R/A	Road Allowance
N. P.	Unit not penetrated
—	Unit not present due to erosion or change of facies.

Notes

1) Most of the formation top depths listed for Alberta and Montana wells were obtained from well logs available in the files of the Saskatchewan Department of Mineral Resources. However, those Alberta wells with an asterisk * beside them are ones for which well logs were not available and the formation top depths were interpreted by the author from information in the Alberta Conservation Board Schedules of Wells (1949 to 1965).

2) Those kelly bushing elevations that are indicated as approximate have been estimate from topographic maps, since the elevation was not listed on the well log.

3) Those formation top depths with (E) indicate that the top of the formation is an erosional one.

4) Those formation top depths that are indicated as approximate are ones for which the formation top was slightly below the bottom of the well and was estimated from the regional trends.

Well Name	Location	Kelly Bushing Elevation (feet above sea level)	Torquay Formation: Top of Unit 2 (feet below K.B.)	Birdbear Formation: Top of Upper Member (feet below K.B.)	Birdbear Formation: Top of Lower Member (feet below K.B.)	Duperow Formation: Top of Seward Member (feet below K.B.)	Duperow Formation: Top of Wymark Member (feet below K.B.)	Duperow Formation: Top of Elstow Member (feet below K.B.)	Duperow Formation: Top of Saskatoon Member (feet below K.B)	Top of Souris River Formation (feet below K.B.)
Soc. Sohio Congress 13-13	13-13- 9- 1W3	2391	5603	5642	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
Farmers Mutual Old Wives Lake 10-35	10-35-11- 1W3	2259	5188	5240	5334	5365	5519	5907	5924	5987
Imp. Luke Valley 12-6-19-1	12- 6-19- 1W3	1962	4167	4220	4288	4329	4535	4917	4947	5013
T.W. Eyebrow Crown No. 1	1-20-23- 1W3	1924	3022	3082	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
T.W. Eyebrow Crown No. 2	5-30-23- 1W3	1917	3011	3078	3137	3178	3388	3788	3820	3890
T.W. Craik Crown No. 2	4-29-25- 1W3	2064	2848	2930	3022	3053	N.P.	N.P.	N.P.	N.P.
Imp. Davidson No. 1	16- 8-27- 1W3	2064	—	2995	3051	3100	3280	3720	3780	3845
T.W. Allan Crown No. 1	4-10-33- 1W3	1762	—	2110 (E)	2146	2221	2407	2723	2767	2845
T.W. Allan Crown No. 16-11	16-11-33- 1W3	1759	—	—	—	2184 (E)	2330	2670	2712	2795
U.S. B & C Allan No. 13-11	13-11-34- 1W3	1735	—	—	—	—	2182 (E)	2532	2562	2643
U.S. B& C Allan 1-12	1-12-34- 1W3	1734	—	—	—	2208 (E)	2318	2625	2672	2760
U.S. B & C Allan 1-12A-34-1	1-12-34- 1W3	1731	—	—	—	2169 (E)	2300	2612	2658	2748
U.S. B & C Allan 16-14	16-14-34- 1W3	1720	—	—	—	2090 (E)	2150	2511	2560	2640
U.S. B & C Allan 1-17	1-17-34- 1W3	1750	—	—	—	2125 (E)	2207	2563	2605	2691
U.S. B & C Elstow 5-22-A	5-22-34- 1W3	1731	—	—	—	2126 (E)	2227	2511	2556	2645
Altair Elstow 15-24	15-24-34- 1W3	1729	—	—	—	2090 (E)	2240	2526	2566	2654
U. S. B & C Elstow No. 1-25	1-25-34- 1W3	1742	—	—	—	2130 (E)	2199	2552	2592	2660
U. S. B & C Elstow 9-26	9-26-34- 1W3	1735	—	—	—	2115 (E)	2165	2492	2530	2620

Well Name	Location	Kelly Bushing Elevation (feet above sea level)	Torquay Formation: Top of Unit 2 (feet below K.B.)	Birdbear Formation: Top of Upper Member (feet below K.B.)	Birdbear Formation: Top of Lower Member (feet below K.B.)	Duperow Formation: Top of Seward Member (feet below K.B.)	Duperow Formation: Top of Wymark Member (feet below K.B.)	Duperow Formation: Top of Elstow Member (feet below K.B.)	Duperow Formation: Top of Saskatoon Member (feet below K.B)	Top of Souris River Formation (feet below K.B.)
U. S. B & C Elstow 9-27	9-27-34- 1W3	1735	--	--	--	2094 (E)	2133	2475	2514	2603
U.S. B & C Elstow 9-28	9-28-34- 1W3	1727	--	--	--	2110 (E)	2153	2462	2511	2599
U. S. B & C Elstow 4-29-A	4-29-34- 1W3	1734	--	--	--	2114 (E)	2190	2491	2530	2621
U. S. B & C Elstow 9-33	9-33-34- 1W3	1731	--	--	--	2092 (E)	2143	2457	2497	2587
U. S. B & C Elstow 8-34	8-34-34- 1W3	1717	--	--	--	2069 (E)	2118	2452	2483	2570
U. S. B & C Elstow 9-35	9-35-34- 1W3	1727	--	--	--	--	2099 (E)	2447	2487	2577
Elstow 16-9	16- 9-35- 1W3	1734	--	--	--	2090 (E)	2140	2400	2438	2510
Elstow 5-26	5-26-35- 1W3	1779	--	--	--	2169 (E)	2198	2473	2510	2596
U S P St Denis No. 1	9-29-36- 1W3	1845	--	--	1990 (E)	2027	2243	2427	2460	2549
W. R. et al St. Denis 4-16-37-1	4-16-37- 1W3	1833	--	--	--	1980 (E)	2191	2400	2433	2517
W. R. St. Denis 1-22-37-1	1-22-37- 1W3	1830	--	1880 (E)	1886	1963	2167	2362	2400	2482
U S P Vonda No. 1-A	13-33-37- 1W3	1883	--	1958 (E)	1979	2063	2256	2442	2475	2561
W. R. et al St. Denis 7-2-38- 1	7- 2-38- 1W3	1927	--	--	--	2028 (E)	2208	2408	2439	2520
W. R. et al St. Denis 6-16-38-1	6-16-38- 1W3	1937	--	--	2022 (E)	2040	2230	2415	2446	2527
Britalta Smuts No. 1	16-10-40- 1W3	1784	--	--	--	--	1858 (E)	N.P.	N.P.	N.P.
Canpet et al Duck Lake 11-15	11-15-46- 1W3	1635	--	--	--	--	1358 (E)	1397	1432	1518
Soc. Sohio Canopus 25-12	12-25- 3- 2W3	3221	6873	6911	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.

Well Name	Location	Kelly Bushing Elevation (feet above sea level)	Torquay Formation: Top of Unit 2 (feet below K.B.)	Birdbear Formation: Top of Upper Member (feet below K.B.)	Birdbear Formation: Top of Lower Member (feet below K.B.)	Duperow Formation: Top of Seward Member (feet below K.B.)	Duperow Formation: Top of Wymark Member (feet below K.B.)	Duperow Formation: Top of Elstow Member (feet below K.B.)	Duperow Formation: Top of Saskatoon Member (feet below K.B)	Top of Souris River Formation (feet below K.B.)
Soc. Sohio Elm Springs 14-12	12-14- 5- 2W3	2780	6319	6364	6447	6465	N.P.	N.P.	N.P.	N.P.
Johnston Lake Crown No. 1	9-20-12- 2W3	2421	5135	5183	5268	5307	5469	5843	5858	5929
T.W. Eyebrow Crown No. 3	7-3-21- 2W3	2024	3856	3933	3988	4019	4235	4610	4659	4712
Sifto Salt Tugaske 14-34-22-2	14-34-22- 2W3	1895	3063	3124	3187	3222	3409	3819	3867	3919
El Centro and Associates No. 12-35	12-35-22- 2W3	1885	3053	3124	3183	3220	3410	3811	3857	3927
Sifto Salt (1960) Tugaske 4-10-23-2	4-10-23- 2W3	1883	3014	3077	3135	3175	3365	3769	3817	3885
U. S. B & C Bradwell No. 9	9-29-33- 2W3	1768	—	2084 (E)	2130	2214	2405	2646	2693	2758
U. S. B & C Bradwell No. 16	16-11-34- 2W3	1773	—	—	—	2162 (E)	2336	2594	2635	2713
U S P Bradwell No. 1	12-32-34- 2W3	1759	—	2050 (E)	2088	2175	2370	2609	2634	2730
P C A Saskatoon No. 8	5-34-35- 2W3	1731	—	—	—	2102 (E)	2200	2430	2475	2558
P C A Saskatoon No. 4	12- 7-36- 2W3	1778	—	1992 (E)	2047	2132	2288	2520	2568	2653
P C A Saskatoon No. 7	4-22-36- 2W3	1856	—	—	2097 (E)	2155	2323	2530	2574	2650
Duval Aberdeen 3-30-37-2	3-30-37- 2W3	1776	—	—	1921 (E)	2002	2209	2396	2437	2517
Aberdeen No. 1	9-6-39- 2W3	1699	—	—	—	1780 (E)	N.P.	N.P.	N.P.	N.P.
Britalta Hague No. 1	9- 6-41- 2W3	1586	—	—	—	1613 (E)	N.P.	N.P.	N.P.	N.P.
Britalta North Cabin No. 1	16-26-47- 2W3	1652	—	—	—	—	1560 (E)	1572	1611	1710

			Torquay Formation	Birdbear Formation		Duperow Formation				
Well Name	Location	Kelly Bushing Elevation (feet above sea level)	Top of Unit 2 (feet below K.B.)	Top of Upper Member (feet below K.B.)	Top of Lower Member (feet below K.B.)	Top of Seward Member (feet below K.B.)	Top of Wymark Member (feet below K.B.)	Top of Elstow Member (feet below K.B.)	Top of Saskatoon Member (feet below K.B)	Top of Souris River Formation (feet below K.B.)
Soc. Sohio Strathallen 23-5	5-23- 2- 3W3	3026	6593	6640	6720	6735	6896	7221	7266	7318
Sohio Standard Regent Wood Mountain No. 1	9-18- 3- 3W3	3246	6731	6768	6852	6877	7032	7402	7440	7485
W. R. Wood Mountain 12-19-4-3	12-19- 4- 3W3	2997	6413	6442	6532	6549	6707	7064	7102	7144
Soc. Sohio Limerick No. 35-6	6-35- 8- 3W3	2502	5690	5720	5796	5849	6007	N.P.	N.P.	N.P.
T.W. Signal Johnston Lake Crown 2-2	2- 2-13- 3W3	2331	5104	5155	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
Parkbeg Crown No. 1	10-32-18- 3W3	2217	4505	4566	4619	4653	4815	5220	5253	5316
U. S. B & C Bradwell No. 13	13-11-34- 3W3	1745	—	2132 (E)	2187	2263	2453	2690	2730	2820
Anglo Amer. Gridoil Clavet 5-34	5-34-34- 3W3	1752	—	2241 (E)	2288	2384	2579	2797	2842	2936
P C A Saskatoon No. 6	1-34-35- 3W3	1716	—	2057 (E)	2130	2219	2364	2622	2677	2744
P C A Saskatoon No. 9	13- 2-36- 3W3	1736	—	1942 (E)	2006	2094	2257	2473	2527	2595
P C A Saskatoon No. 2	6-16-36- 3W3	1740	—	—	1989 (E)	2061	2232	2446	2493	2562
P C A Saskatoon No. 11	3-18-36- 3W3	1785	—	2014 (E)	2088	2174	2342	2567	2613	2691
P C A Saskatoon No. 5	13-24-36- 3W3	1752	—	1933 (E)	2012	2098	2261	2483	2538	2605
P C A Saskatoon No. 10	4- 4-37- 3W3	1782	—	1917 (E)	1996	2078	2250	2444	2496	2553
Saskatoon 16-17	16-17-37- 3W3	1946	—	2063 (E)	2096	2176	2366	2561	2608	2668
Sohio Standard Wood Mountain No. 1	16-10- 4- 4W3	3118	6550	6571	6666	6683	6848	7197	7236	7279

Well Name	Location	Kelly Bushing Elevation (feet above sea level)	Torquay Formation: Top of Unit 2 (feet below K.B.)	Birdbear Formation: Top of Upper Member (feet below K.B.)	Birdbear Formation: Top of Lower Member (feet below K.B.)	Duperow Formation: Top of Seward Member (feet below K.B.)	Duperow Formation: Top of Wymark Member (feet below K.B.)	Duperow Formation: Top of Elstow Member (feet below K.B.)	Duperow Formation: Top of Saskatoon Member (feet below K.B)	Top of Souris River Formation (feet below K.B.)
B A Baciu 15-36	15-36- 6- 4W3	2531	5775	5803	5877	5947	6098	6481	6505	6563
Christie Quintana Melaval No. 1	2-14- 8- 4W3	2562	5639	5676	5749	5793	5957	6319	6336	6399
Sun Christie Gravelbourg No. 7-16	7-16- 9- 4W3	2560	5646	5686	5769	5802	5976	6326	6349	6419
T.W. Wood River Crown No. 1-A	4-18-10- 4W3	2308	5293	5333	5418	5451	5617	5996	6014	6076
Paramount et al Chaplin Lake 13-21	13-21-16- 4W3	2240	4675	4746	4789	4828	N.P.	N.P.	N.P.	N.P.
Imp. T.W. Strongfield 12-16-26-4	12-16-26- 4W3	2000	3344	3432	3533	3583	3786	4192	4232	4319
Dundurn Crown No. 5	1- 7-33- 4W3	1706	2120	2160	2227	2310	2521	2735	2782	2873
Midas No. 1	4- 2-36- 4W3	1722	2105 (E)	2150	2220	2312	2505	2702	2745	2820
P C A Saskatoon No. 3	16-26-36- 4W3	1807	--	2095	2176	2252	2453	2623	2673	2700
Southwest No. 2	16-32-36- 4W3	1697	--	2225	2310	2381	2586	2786	2823	2893
Southwest No. 3	15- 9-37- 4W3	1686	--	1902 (E)	1917	1997	2192	2383	2438	2502
Saskatoon No. 12-19	12-19-37- 4W3	1645	--	1903 (E)	1963	2020	2230	2482	2522	2587
P C A Saskatoon No. 1	13-22-37- 4W3	1669	--	--	--	1890 (E)	2079	2302	2342	2420
Amco No. 1	6-25-37- 4W3	1713	--	1825 (E)	1858	1918	2108	2315	2362	2435
G. P. Saskatoon 6-12	6-12-38- 4W3	1671	--	--	--	1865 (E)	1980	2258	2297	2360
Grt Plns Decalta Osler 16-24-39-4	16-24-39- 4W3	1624	--	--	--	1735 (E)	1849	2150	2190	2270

Well Name	Location	Kelly Bushing Elevation (feet above sea level)	Torquay Formation: Top of Unit 2 (feet below K.B.)	Birdbear Formation: Top of Upper Member (feet below K.B.)	Birdbear Formation: Top of Lower Member (feet below K.B.)	Duperow Formation: Top of Seward Member (feet below K.B.)	Duperow Formation: Top of Wymark Member (feet below K.B.)	Duperow Formation: Top of Elstow Member (feet below K.B.)	Duperow Formation: Top of Saskatoon Member (feet below K.B)	Top of Souris River Formation (feet below K.B.)
Winsal Osler 3-28	3-28-39- 4W3	1706	--	--	--	1802 (E)	1910	2218	2270	2332
Britalta Rosthern No. 1	13-36-41- 4W3	1724	--	--	--	--	1905 (E)	N.P.	N.P.	N.P.
Calstan Laird 16-16	16-16-43- 4W3	1722	--	--	--	--	--	1952 (E)	1960	2058
T.W. Placid Hawarden Crown No. 1	12-10-29- 5W3	2014	3039	3114	3172	3257	3456	3868	3917	3994
Dundurn Crown No. 1	4-22-31- 5W3	1741	2140	2196	2244	2340	2550	2911	2970	N.P.
Dundurn Crown No. 2	8-17-32- 5W3	1727	2080	2128	2167	2273	2512	2824	2862	2961
Imp. Dundurn 13-18-32-5	13-18-32- 5W3	1703	2080	2144	2208	2297	2515	2872	2912	3005
Midas No 2	1- 7-35- 5W3	1628	2560	2617	2695	2788	2958	N.P.	N.P.	N.P.
Saskatoon Exhibition #1	15-17-36- 5W3	1647	1886	1932	2014	2100	N.P.	N.P.	N.P.	N.P.
Inter. Rochdale 4-26-37-5	4-26-37- 5W3	1654	--	--	1979 (E)	2034	2203	2498	2547	2613
Britalta Waldheim No. 1	2-20-42- 5W3	1779	--	--	--	--	2012 (E)	2078	2118	2205
Amerada Shell Crown S-0 13-17	13-17- 3- 6W3	3255	6490	6508	6602	6652	6822	7142	7168	7244
Kelstern Crown No. 1	5-27-15- 6W3	2417	4894	4956	5016	5036	5218	5608	5630	N.P.
B. A. Moore 6-27	6-27-15- 6W3	2411	4835	4871	4955	4983	5161	5557	5584	5655
Imp. Lawson No. 1	16-13-21- 6W3	2214	3955	4130	4190	4240	4460	4880	4910	5000
T.W. Imp. Elbow Crown No. 2	5-13-23- 6W3	1982	3613	3766	3815	3846	4050	4464	4507	4580
Imp. Wingello 14-21-31-6	14-21-31- 6W3	1710	2148	2221	2276	2365	2595	2946	2986	3069

Well Name	Location	Kelly Bushing Elevation (feet above sea level)	Torquay Formation	Birdbear Formation		Duperow Formation				
			Top of Unit 2 (feet below K.B.)	Top of Upper Member (feet below K.B.)	Top of Lower Member (feet below K.B.)	Top of Seward Member (feet below K.B.)	Top of Wymark Member (feet below K.B.)	Top of Elstow Member (feet below K.B.)	Top of Saskatoon Member (feet below K.B)	Top of Souris River Formation (feet below K.B.)
Dundurn Crown No. 4	5- 1-32- 6W3	1708	2165	2249	2332	2406	2607	N.P.	N.P.	N.P.
Dundurn Crown No. 3	2-25-32- 6W3	1626	2074	2122	2228	2308	2503	N.P.	N.P.	N.P.
D. S. P. Saskatoon No. 5	4- 4-36- 6W3	1683	--	1958 (E)	1982	2069	2258	2564	2609	2688
Duval Corp Saskatoon 5-7-36-6	5- 7-36- 6W3	1630	--	1872 (E)	1915	2000	2180	2472	2523	2611
Duval Saskatoon 1-16-36-6	1-16-36- 6W3	1660	--	1941 (E)	2018	2099	2268	2499	2550	2632
Midas No. 3	14-28-36- 6W3	1664	--	1876 (E)	1904	1988	2165	2467	2510	2590
Duval Saskatoon 5-30-36-6	5-30-36- 6W3	1663	--	1866 (E)	1893	1969	2152	2450	2500	2585
DSP 4-2A-37-6	4- 2-37- 6W3	1660	--	1814 (E)	1888	1960	2140	2428	2480	2547
D. S. P. Saskatoon No. 2	15- 2-37- 6W3	1657	--	1877 (E)	1939	2018	2198	2494	2527	2603
DSP 8-11-37-6	8-11-37- 6W3	1655	--	2119 (E)	2178	2258	2440	2747	2780	2845
W. R. et al Cory 1-34-37-6	1-34-37- 6W3	1682	--	--	1992 (E)	2013	2198	2516	2558	2624
T. W. Signal Horse Crown 12-17	12-17-16- 7W3	2512	4983	5040	5110 (approx)	N.P.	N.P.	N.P.	N.P.	N.P.
Imp. Horse No. 1	1- 6-18- 7W3	2332	4635	4690	4740	4773	4964	5350	5380	5455
Outlook Crown No. 1	7-20-30- 7W3	1776	2295	2370	2449	2536	2756	3104	3150	3247
Pan Am A 1 West Saskatoon 14-10-35-7	14-10-35- 7W3	1725	--	2083 (E)	2121	2200	2376	2671	2711	2794
Duval Saskatoon 1-25-35-7	1-25-35- 7W3	1664	--	1997 (E)	2052	2141	2300	2564	2602	2689

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			Top of Unit 2 (feet below K.B.)	Top of Upper Member (feet below K.B.)	Top of Lower Member (feet below K.B.)	Top of Seward Member (feet below K.B.)	Top of Wymark Member (feet below K.B.)	Top of Elstow Member (feet below K.B.)	Top of Saskatoon Member (feet below K.B)	Top of Souris River Formation (feet below K.B.)
Duval Corp Saskatoon 16-34-35-7	16-34-35- 7W3	1683	--	--	1988 (E)	2072	2252	2564	2604	2691
Duval Saskatoon 4-16-36-7	4-16-36- 7W3	1683	--	1940 (E)	1959	2050	2235	2525	2565	2652
D.S.P. Saskatoon No. 4	8-22-36- 7W3	1681	--	1920 (E)	1930	2009	2201	2499	2540	2628
Duval Saskatoon 1-32-36-7	1-32-36- 7W3	1659	--	--	1887 (E)	1897	2089	2410	2450	2531
D.S.P. Saskatoon No. 1	1-11-37- 7W3	1663	--	--	--	1898 (E)	2080	2406	2448	2519
Midas No. 4	13-11-37- 7W3	1666	--	--	--	1901 (E)	2078	2406	2450	2520
D.S.P. Saskatoon No. 3	4-28-37- 7W3	1678	--	--	--	1863 (E)	2047	2364	2405	2483
Cdn. Exp. Ltd. Langham 1-32-38-7	1-32-38- 7W3	1705	--	--	--	--	1997 (E)	2347	2388	2477
Sohio No. 2 Stratigraphic Test	7-22-39- 7W3	1725	--	--	--	--	2078 (E)	2310	2358	2430
Sohio Standard Langham No. 1	9-18-40- 7W3	1698	--	--	--	--	1905 (E)	2187	2230	2304
Int. Helium Wood Mountain 10-3	10- 3- 5- 8W3	2798	5866	5887	5970	6008	6181	6524	6540	6606
Int. Helium Mankota 2-7-5-8	2- 7- 5- 8W3	2729	5783	5812	5890	5927	6100	6450	6466	6545
Int. Helium Wood Mountain 12-10-5-8	12-10- 5- 8W3	2839	5900	5928	6005	6042	6215	6562	6576	6645
T.W. Glenbain Crown No. 1	8-22-10- 8W3	2499	5332	5382	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.

Well Name	Location	Kelly Bushing Elevation (feet above sea level)	Torquay Formation: Top of Unit 2 (feet below K.B.)	Birdbear Formation: Top of Upper Member (feet below K.B.)	Birdbear Formation: Top of Lower Member (feet below K.B.)	Duperow Formation: Top of Seward Member (feet below K.B.)	Duperow Formation: Top of Wymark Member (feet below K.B.)	Duperow Formation: Top of Elstow Member (feet below K.B.)	Duperow Formation: Top of Saskatoon Member (feet below K.B)	Top of Souris River Formation (feet below K.B.)
Stelter No. 4	4-28-14- 8W3	2566	5157	5203	5258	5284	N.P.	N.P.	N.P.	N.P.
Horse Crown No. 1	16-25-16- 8W3	2354	4710	4760	4818	4846	5022	5410	5435	5498
Birsay Crown No. 1	13- 4-25- 8W3	2166	3680	3778	3832	3907	4155	4540	4588	4660
Birsay Crown No. 2	4-15-25- 8W3	2058	3653	3720	3787	3815	4028	N.P.	N.P.	N.P.
T.W. Swanson Crown No. 2	16- 9-32- 8W3	1753	2290	2324	2387	2482	2668	2952	3000	3100
W. James Donavon 16-34-32-8	16-34-32- 8W3	1740	2247	2286	2355	2443	2630	2895	2940	3025
W. James Saskatoon 16-22-33-8	16-22-33- 8W3	1747	2265	2268	2350	2452	2616	2856	2894	2982
C.M. and S. Delisle 16-28-34-8	16-28-34- 8W3	1736	—	2232	2308	2397	2572	2804	2842	2932
C.M. and S. Delisle 15-32-34-8	15-32-34- 8W3	1701	—	2233	2312	2393	2582	2817	2857	2939
C.M. and S. Vanscoy 13-1-35-8	13- 1-35- 8W3	1729	—	2152	2237	2323	2504	2738	2777	2865
C.M. and S. Vanscoy 16-6-35-8	16- 6-35- 8W3	1667	--	2186 (E)	2218	2305	2462	2714	2754	2842
C.M. and S. Vanscoy 16-8-35-8	16- 8-35- 8W3	1676	--	2134	2192	2279	2458	2688	2726	2810
C.M. and S. Vanscoy 4-10-35-8	4-10-35- 8W3	1715	—	2140 (E)	2200	2286	2463	2701	2741	2833
C.M. and S. Vanscoy 13-11-35-8	13-11-35- 8W3	1713	—	2099 (E)	2166	2256	2432	2663	2701	2784

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C.M. and S. Vanscoy 11-16-35-8	11-16-35- 8W3	1675	—	2115	2199	2277	2454	2680	2718	2804
C.M. and S. Vanscoy 13-16 35-8	13-16-35- 8W3	1663	—	—	—	2282 (E)	2419	2650	2690	2776
C.M. and S. Vanscoy 4-18-35-8	4-18-35- 8W3	1663	—	2149	2234	2321	2500	2714	2754	2839
C.M. and S. Vanscoy 4-20-35-8	4-20-35- 8W3	1658	—	2118 (E)	2176	2263	2452	2668	2708	2796
C.M. and S. Vanscoy 4-22 35-8	4-22-35- 8W3	1660	—	2086	2173	2255	2438	2668	2708	2792
C.M. and S. Vanscoy 13-23-35-8	13-23-35- 8W3	1664	—	2062 (E)	2106	2188	2365	2614	2654	2738
C.M. and S. Vanscoy 4-28-35-8	4-28-35- 8W3	1652	—	2042 (E)	2098	2183	2363	2599	2637	2719
C.M. and S. Vanscoy 14-29-35-8	14-29-35- 8W3	1671	—	—	2104 (E)	2190	2380	2614	2656	2738
C.M. and S. Vanscoy 4-30-35-8	4-30-35- 8W3	1670	—	2175 (E)	2243	2330	2511	2750	2790	2875
Britalta Hawoods No. 1	15-21-36- 8W3	1649	—	—	1943 (E)	2020	N.P.	N.P.	N.P.	N.P.
F. S. Grandora No. 13-22	13-22-36- 8W3	1656	—	—	1952 (E)	1988	2183	2480	2522	2605
Christie Mitchell Dunfermline No. 13-1	13- 1-37- 8W3	1664	—	—	—	1903 (E)	2098	2435	2478	2567
N.P. Co. Asquith No. 16-6	16- 6-37- 8W3	1640	—	—	1945 (E)	2011	2199	2466	2507	2597

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F.S. Dunfermline No. 13-22	13-22-37- 8W3	1650	—	—	—	1881 (E)	2055	2352	2393	2474
Philmao No. 12-11	12-11-38- 8W3	1648	—	—	—	—	1894 (E)	2270	2322	2392 (approx)
Cdn. Expl. Langham A1-2-39-8	1- 2-39- 8W3	1662	—	—	—	1906 (E)	1954	2255	2297	2368
Sohio No. 3 Stratigraphic Test Well	13-12-40- 8W3	1698	—	—	—	—	1957 (E)	2265	2300	2368
West Cal. Wideview No. 6-29	6-29- 2- 9W3	3271	6180	6198	6280	6317	6490	6832	6842	6917
Amerada Shell Crown S-F 5-11	5-11- 6- 9W3	2757	5768	5810	5892	5922	6107	6458	6475	6541
Wills No. 2	2- 5-12- 9W3	2486	5188	5230	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
Vanguard Crown No. 1	14-30-12- 9W3	2676	5235	5275	5332	5358	5548	5916	5936	6005
Vindeg No. 6	6-28-22- 9W3	2216	4082	4143	4194	4220	4436	4826	4872	4955
Swanson Crown No. 1	4- 8-32- 9W3	1774	2295	2345	2395	2508	2767	N.P.	N.P.	N.P.
C. M. and S. Eagle 4-11-35-9	4-11-35- 9W3	1762	—	2434 (E)	2484	2551	2706	2895	2935	3020
C.M. and S. Eagle 4-12-35-9	4-12-35- 9W3	1733	—	2292	2375	2460	2638	2852	2893	2979
C.M. and S. Eagle 16-22-35-9	16-22-35- 9W3	1770	—	2278 (E)	2330	2408	2598	2820	2860	2948
C.M. and S. Eagle 4-24-35-9	4-24-35- 9W3	1728	—	2160	2252	2336	2497	2758	2800	2885

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C.M. and S. Eagle 4-36-35-9	4-36-35- 9W3	1754	—	2200 (E)	2252	2334	2518	2741	2782	2862
F.S. Asquith 4-16	4-16-36- 9W3	1763	—	—	2178	2267	2447	2669	2700	2795
N.P. Co. Asquith No. 13-14	13-14-37- 9W3	1658	—	—	—	1966 (E)	2150	2400	2440	2522
Prairie Inter. Rock 4-36	4-36-39- 9W3	1623	--	--	—	—	1932 (E)	2168	2212	2288
Canso Alb. Craigmore No. 1	13- 4-44- 9W3	1980	—	—	—	—	2492 (E)	2603	2645	2724
G. T.W. Burns No. 12	12-14-10-10W3	2510	5366	5416	5475	5505	N.P.	N.P.	N.P.	N.P.
Braddock Crown No. 1	5- 7-14-10W3	2654	5039	5120	5170	5214	Formation Badly Brecciated			5920
G. T.W. Sabine 9	9-27-14-10W3	2591	5126	5172	5226	5250	5442	5820	5847	5923
G. T.W. Rice No. 5	5-34-[illegible]-10W3	2223	4244	4320	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
G. T.W. Burrell No. 9	9-27-22-10W3	2390	4223	4290	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
Imp. Rosedale 4-2-24-10	4- 2-24-10W3	2129	3887	3947	4005	4030	4244	4613	4660	4736
Imp. T.W. Anerley 13-21-27-10	13-21-27-10W3	2112	3349	3416	3500	N.P.	N.P.	N.P.	N.P.	N.P.
G. T.W. Hughes No. 9	9-32-29-10W3	1888	[illegible]	2599	2678	2764	2994	3362	3412	3500
B.A. T.W. Laura Crown No. 16-29	16-29-33-10W3	1822	—	2420	2504	2560	N.P.	N.P.	N.P.	N.P.
C.H. and S. Asquith 1-4-37-10	1- 4-37-10W3	1762	—	2420 (E)	2440	2510	2687	2935	2973	3062
Albercan Crown #3	1-29-43-10W3	1965	—	—	—	—	2346 (E)	2408	2444	2520

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Amerada Shell Crown S A 5-31	5-31- 2-11W3	2735	5223	5241	5328	5351	5528	5872	5879	5960
Shell Wood Mountain No. 1	7-34- 9-11W3	2544	5276	5320	5377	5403	5579	5955	5975	6056
G. T.W. Meaden No. 12	12-35-21-11W3	2340	4061	4121	4172	4198	4418	4818	4866	4948
T. W. Beechy Crown No. 1	1-29-23-11W3	2411	3787	3840	3911	3940	4150	4548	4592	4685
Imp. Dinsmore 1-32-27-11	1-32-27-11W3	1969	3347	3409	3494	3575	3803	4190	4240	4328
G. T.W. Cruse 13	13-18-29-11W3	1904	2640	2698	2779	N.P.	N.P.	N.P.	N.P.	N.P.
G. T.W. Watt No. 1	1-20-30-11W3	1952	2583	2637	2720	N.P.	N.P.	N.P.	N.P.	N.P.
G. T.W. Stonyridge 11-11	11-11-31-11W3	1873	2460	2506	2577	N.P.	N.P.	N.P.	N.P.	N.P.
Sohio Red Creek Oil and Gas Arelee No. 1	3-29-37-11W3	1902	—	2168 (E)	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
Cont. Pot. Arelee 7-4-38-11	7- 4-38-11W3	1806	—	—	2161 (E)	2229	2437	2698	2732	2812
Sohio Red Creek Oil and Gas Areleo No. 2	12- 9-38-11W3	1809	—	—	2064 (E)	2118	N.P.	N.P.	N.P.	N.P.
Lib. Canso Speers No. 14-14	14-14-43-11W3	1944	—	—	—	—	1970 (E)	2035	2066	2154 (approx)
Lib. Canso Speers No. 16-20	16-20-43-11W3	1940	—	—	—	—	—	1990 (E)	2012	2110
Alb. Crown Ltd. 13-32	13-32-45-11W3	2216	—	—	—	—	—	2420 (E)	2452	2534
Shell Wood Mtn. #2	13-36- 1-12W3	2687	5116	5137	5226	5262	5439	5749	5777	5842
G. T.W. Cook No. 13	13- 4-30-12W3	1944	2668	2723	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
T.W. Imp. Brigbin Crown No. 1	10-32-30-12W3	1971	2643	2688	2741	N.P.	N.P.	N.P.	N.P.	N.P.

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G. T.W. Brisbin No. 15-21	15-21-31-12W3	1938	2535	2573	2636	2738	2962	3318	3378	3452
G. T.W. Hansen No. 16	16-11-35-12W3	1844	--	2300	2405	2474	2678	2884	2937	3043
Sohio Red Creek Oil and Gas Arelee No. 3	14-11-37-12W3	1865	--	2171 (E)	2192	2277	2460	N.P.	N.P.	N.P.
Sohio Red Creek Arelee No. 4	15- 5-38-12W3	1939	--	2232 (E)	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
Sohio Red Creek Arelee No. 5	13-11-40-12W3	1894	--	--	--	2259 (E)	2392	2647	2692	2773 (approx)
Maymont No. 1	1-28-41-12W3	1914	--	--	--	2078 (E)	N.P.	N.P.	N.P.	N.P.
Cont. and Assoc. Maymont No. 13-11	13-11-42-12W3	1826	--	--	--	--	1924 (E)	2238	2270	2358
Alb. Crown 4-44-12	13- 4-44-12W3	1958	--	--	--	--	--	2462 (E)	2500	2582
Amerada Shell Crown S E 10-26	10-26- 1-13W3	2692	4904	4928	5003	5043	5222	5522	5525	5628
Imp. McC. & Col. Val Marie #16-23	16-23- 4-13W3	2802	5344	5374	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
Swift Current No. 1	11-20-13-13W3	2893	5294	5336	5370	5405	5600	5995	6015	6085
Williston S.C. Harlow No. 4-19	4-19-15-13W3	2441	4768	4816	4860	4882	5083	N.P.	N.P.	N.P.
Kyle Crown No. 1	3-32-21-13W3	2665	4127	4185	4237	4262	4471	5012	5053	5140
Elrose Crown No. 1	4- 6-25-13W3	1995	3033	3080	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
T.W. Imp. Forgan Crown No. 1	4-16-27-13W3	1927	2762	2822	2907	N.P.	N.P.	N.P.	N.P.	N.P.

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			Top of Unit 2 (feet below K.B.)	Top of Upper Member (feet below K.B.)	Top of Lower Member (feet below K.B.)	Top of Seward Member (feet below K.B.)	Top of Wymark Member (feet below K.B.)	Top of Elstow Member (feet below K.B.)	Top of Saskatoon Member (feet below K.B)	
G. T.W. Bents No. 12-27	12-27-33-13W3	1979	2511	2538	2608	2702	2906	3134	3187	3291
El Pen Rey No. 1	6-15-36-13W3	2094	2424 (E)	2453	2540	2619	2800	N.P.	N.P.	N.P.
Ceepee Riley Lake 3-4	3- 4-39-13W3	2385	--	2460 (E)	2467	2553	2768	3094	3140	3210
Shell Rio Tinto Whitkow No. 1	4-30-46-13W3	2074	--	--	--	--	2262 (E)	2287	2318	2400
Shell Rio Tinto Whitkow No. 2	14-34-47-13W3	2394	--	--	--	--	--	2438 (E)	2469	2502
T.W. Wymark Crown No. 1	3-10-14-14W3	2789	5104	5151	5195	5217	5422	5828	5848	5936
B.A. Wilhelm 1-9	1- 9-17-14W3	2387	4472	4521	4566	4586	4794	5196	5243	5317
Can.Helium Atlas Hungnees 8-17-18-14	8-17-18-14W3	2471	4547	4600	4652	4672	4896	5300	5322	5421
Tex. Fortune A8-14	8-14-29-14W3	1976	2804	2853	2933	3032	3262	3668	3715	3808
Imp. Fortune 13-20-30-14	13-20-30-14W3	1946	3023	3118	3189	3295	3517	3890	3938	4041
T.W. Valley Centre Crown No. 1	16-10-33-14W3	2023	2596	2650	2736	2828	N.P.	N.P.	N.P.	N.P.
T.W. Biggar Crown No. 2	9-20-34-14W3	2153	--	2629	2722	2800	N.P.	N.P.	N.P.	N.P.
T.W. Biggar Crown No. 1	4-30-35-14W3	2158	--	2553	2660	N.P.	N.P.	N.P.	N.P.	N.P.
Eagle Hill No. 2	3- 6-36-14W3	2175	--	2600	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
Edoran Christie Biggar No. 1	7-18-36-14W3	2168	--	2540	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.

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Calstan North Biggar Prov. 16-12-38-14	16-12-38-14W3	2286	—	2423	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
Ceepee Koppel Forest 8-3	8- 3-40-14W3	2432	—	—	—	2517 (E)	2740	3003	3045	3133
Heath Paige No. 1	16- 3-40-14W3	2391	—	—	—	2480 (E)	N.P.	N.P.	N.P.	N.P.
Spinney Hill No. 1	16-24-40-14W3	2074	—	—	—	2215 (E)	N.P.	N.P.	N.P.	N.P.
HB Jackfish Lake 12-3-46-14	12- 3-46-14W3	1939	—	—	—	—	2194 (E)	2236	2270	2355
Battrum Crown No. 1	2- 6-19-15W3	2426	4346	4395	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
Imp. T.W. Rosetown No. 12-19-31-15	12-19-31-15W3	2098	—	2962 (E)	2990	3096	N.P.	N.P.	N.P.	N.P.
T.W. Triumph Crown No. 1	8-21-34-15W3	2356	—	2843	2947	3029	N.P.	N.P.	N.P.	N.P.
Allenbee Peak and Assoc. Canso Curthohill No. 1	4-35-37-15W3	2222	—	2608	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
Red Pheasant No. 1	5-32-39-15W3	2325	—	—	—	2580 (E)	2670	2940	2981	3064
S.W.S. Success 3-7	7- 3-17-16W3	2438	4502	4560	4607	4628	4878	5352	5388	5478
Norcanols Pennant No. 1	4-14-18-16W3	2459	4475	4492	4552	4579	4770	5200	5220	5287
Sohio Standard Elrose No. 1	14-12-26-16W3	2059	3058	3095	3176	3271	3492	N.P.	N.P.	N.P.
T.W. Herschel Crown No. 2	15-11-32-16W3	2209	—	2860	2952	3038	N.P.	N.P.	N.P.	N.P.
T.W. Goldburg Crown No. 1	13-22-33-16W3	2391	—	2930	3022	3112	N.P.	N.P.	N.P.	N.P.
Duperow Crown No. 2	4-22-34-16W3	2360	—	2852	2960	3035	3275	3630	3670	3770

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Duperow Crown No. 1	4- 9-35-16W3	2291	--	2686	2791	2871	3105	3450	3498	3592
Alb. Crown Castlewood No. 1	4-12-36-16W3	2135	--	2590	2687	2768	2999	3293	3345	3433
Lib. Canso No. 3	2-32-36-16W3	2080	--	2503 (E)	2565	2659	2878	3177	3222	3320
Lib. Canso New Devon Skyline No. 2	3- 6-37-16W3	2104	--	2437 (E)	2490	2584	2808	3114	3160	3255
Allenbee Peek and Assoc. Canso Salter No. 1	1-29-38-16W3	2185	--	2503 (E)	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
Earle Hills No. 1	8-10-40-16W3	2398	--	--	--	2592 (E)	2740	3030	3071	3146
McColl Frontenac Mosquito No. 6-34	6-34-40-16W3	2372	--	--	--	2660 (E)	2694	N.P.	N.P.	N.P.
Calstan S Battleford Prov. 14-11-42-16	14-11-42-16W3	2099	--	--	--	--	2235 (E)	2448	2485	2580
Nancy No. 2	11- 6-43-16W3	1729	--	--	--	--	1945 (E)	N.P.	N.P.	N.P.
C.S. Battleford No. 1	8-30-43-16W3	1625	--	--	--	--	1841 (E)	1926	1940	2040
Alb. Crown Led 10-7-52-16	10- 7-52-16W3	2299	--	--	--	--	--	--	2116 (E)	2139
Pan Am Crown Al Climax 13-30	13-30- 6-17W3	3201	5908	5948	6000	6026	6243	6605	6632	6707
M.O.W.S. Cantuar X-2-21	2-21-16-17W3	2411	4468	4513	4568	4584	4810	5200	5248	5328
Wartime No. 1	2-14-26-17W3	2071	3076	3105	3182	3276	3535	4068	4118	4204
T.W. Herschel Crown No. 1	13- 9-31-17W3	2021	2680	2700	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.

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Abbey Crown No. 1	3-18-22-19W3	2095	—	3426	3550	N.P.	N.P.	N.P.	N.P.	N.P.
Wilkie No. 1	10-32-39-19W3	2170	—	—	—	2379 (E)	N.P.	N.P.	N.P.	N.P.
Campana Wilkie No. 16-18	16-18-40-19W3	2214	—	—	—	—	2508 (E)	2882	2907	3004
Calvan Saphire Charter Wilkie No. 1	1-29-40-19W3	2216	—	—	—	—	2472 (E)	2830	2870	2962
Campana Wilkie No. 8-30	8-30-40-19W3	2197	—	—	—	—	2445 (E)	2830	N.P.	N.P.
Campana Wilkie No. 8-32	8-32-40-19W3	2217	—	—	—	—	2502 (E)	2883	2910	3004
Rio Prado Edam 13-18	13-18-49-19W3	1830	—	—	—	—	—	—	1932 (E)	N.P.
Rio Prado Edam 4-22	4-22-49-19W3	1899	—	—	—	—	—	—	2010 (E)	N.P.
Rio Prado Mervin 4-8	4- 8-50-19W3	1960	—	—	—	—	—	—	1950 (E)	N.P.
Eastend Crown No. 1	15-11- 6-20W3	3237	5675	5720	5772	5793	6007	6395	6413	6500
T.W. Eastend Crown No. 5-12	5-12- 6-20W3	3251	5699	5729	5797	5818	6030	6409	6453	6508
S.W.P. Tompkins No. 1	14-19-13-20W3	2664	4768	4820	4876	4894	5145	5539	5572	5674
Roy. Kelfield No. 1	8-33-34-20W3	2036	—	2475 (E)	2520	N.P.	N.P.	N.P.	N.P.	N.P.
Calvan Charter Sapphire Wilkie No. 8-15	8-15-40-20W3	2198	—	—	—	—	2525 (E)	2900	2933	N.P.
Campana Wilkie No. 8-24	8-24-40-20W3	2201	—	—	—	2432 (E)	2457	2860	2896	2992
Caldina Oils No. 1	7-32-41-20W3	2153	—	—	—	2272 (E)	2286	2676	2709	2806

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B.A. Gallivan Rose 4-29-43-20	4-29-43-20W3	2039	—	—	—	—	2093 (E)	2328	2352	2469
B A Forsberg 2-11	2-11-50-20W3	1921	—	—	—	—	—	1945 (E)	1960	2137
Battleford Maidotone No 3 Well	1-18-50-20W3	1960	—	—	—	—	—	—	2101 (E)	N.P.
S.W.S. North Eastbrook 4-15	15- 4- 5-21W3	3128	5589	5640	5696	5722	5941	6320	6338	6424
S.W.S. West Roadene 14-7	7-14-18-21W3	2390	4137	4182	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
Imp Netherhill 11-17-27-21	11-17-27-21W3	2318	3284	3320	3392	N.P.	N.P.	N.P.	N.P.	N.P.
Sup. Dodsland No. 1	9-16-32-21W3	2312	2908	2934	3042	3125	3372	3832	3878	3975
Ceepee Dukesbury 13-18	13-18-34-21W3	2195	2527 (E)	2559	2660	N.P.	N.P.	N.P.	N.P.	N.P.
Ceepee Broadacres 13-13	13-13-35-21W3	2219	—	2537	2588	2676	2898	3419	3453	3570
St. Walburg No. 1	14-31-55-21W3	2230	—	—	--	—	—	—	2044 (E)	2094
Nuco Calstan Barthel No 4-22	4-22-57-21W3	1906	—	—	--	—	—	—	1635 (E)	1638
M.O.W.S. Dorrell 32-9	9-32- 6-22W3	3458	5798	5851	5908	5930	6160	6570	6583	6678
D.H.P. Skull Lake No. 1	12-22- 9-22W3	3679	5929	5955	6037	6060	6276	6693	6727	6820
S.W.S. North Beotville 30-3	3-30-18-22W3	2382	3985	4043	4137	4164	4420	N.P.	N.P.	N.P.
H.P. Inglenook No. 1	1- 4-28-22W3	2406	—	3308	3417	3528	3784	4290	4337	4432
Canso New Sup. et al Ermine No. 9-2	9- 2-33-22W3	2243	2720	2795	2870	2945	N.P.	N.P.	N.P.	N.P.

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Sup. Dodsland No. 4	16-10-33-22W3	2245	2678	2720	2835	2916	3159	3678	3722	3825
Zenith Crown No. 1	8-14-37-22W3	2100	—	—	—	2363 (E)	N.P.	N.P.	N.P.	N.P.
Beta No.13	10- 3-39-22W3	1874	—	—	2107 (E)	N.P.	N.P.	N.P.	N.P.	N.P.
Prairie Salt Company No.1	15- 4-40-22W3	2080	—	—	—	2300 (E)	2388	2869	2900	3010
B A Cutknife Rutley 13-14-43-22	13-14-43-22W3	2202	—	—	—	—	2212 (E)	2567	2593	2717
Caldough No. 7	4-18-48-22W3	1902	—	—	—	—	—	—	2060 (E)	2188
Amurex Canso Kieville No. 1-4	4-27-15-23W3	2426	4242	4272	4356	4367	4600	5040	5077	5178
Imp. St Eloi No. 16-13-30-23	16-13-30-23W3	2312	3042	3052	3137	N.P.	N.P.	N.P.	N.P.	N.P.
Coleville Unit No. 5-30-31-23	5-30-31-23W3	2351	2933	2971	3077	3158	3413	3950	3996	4100
R.G.A. Coleville W.D. Well No. 1	15-31-31-23W3	2326	2896	2938	3038	3117	3372	3906	N.P.	N.P.
Stanolind Imp. Beaufield A No. 1	14-17-32-23W3	2317	—	2939	3029	N.P.	N.P.	N.P.	N.P.	N.P.
Alb. Crown 1-20-34-23	1-20-34-23W3	2226	—	2710	2813	2897	3074	3580	3620	N.P.
Woods Paramount Tramping Lake R/A S Bdy 29-36-23	4-29-36-23W3	2337	—	2613	2708	N.P.	N.P.	N.P.	N.P.	N.P.
Woods Paramount Luseland R/A S Bdy 30-36-23	4-30-36-23W3	2320	—	2640	2745	2822	N.P.	N.P.	N.P.	N.P.

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Bata No. 27	16-11-39-23W3	1979	--	2170	2187	2287	N.P.	N.P.	N.P.	N.P.
Bata No. 10	3-15-39-23W3	2175	--	--	2331 (E)	N.P.	N.P.	N.P.	N.P.	N.P.
Bata B 5-22	5-22-39-23W3	2022	--	--	2167 (E)	N.P.	N.P.	N.P.	N.P.	N.P.
Bata No. 8	5-23-39-23W3	1940	--	--	2087 (E)	N.P.	N.P.	N.P.	N.P.	N.P.
Bata No. 2	11-24-39-23W3	1960	--	--	2099 (E)	N.P.	N.P.	N.P.	N.P.	N.P.
Bata No. 21	2-27-39-23W3	2182	--	--	2335 (E)	N.P.	N.P.	N.P.	N.P.	N.P.
W. Pot. Superior Bata No. 1	5-27-40-23W3	2040	--	--	--	2184 (E)	2373	2798	2818	2938
W. Pot. 1-17	1-17-41-23W3	2217	--	--	--	2327 (E)	2430	2913	2930	3050
W. Pot. P. 14-19	14-19-41-23W3	2163	--	--	--	2080 (E)	2378	2848	2865	2985
B A Hillsdale Castellan 13-16-43-23	13-16-43-23W3	2278	--	--	--	--	2324 (E)	2778	2793	2912 (approx.)
Soc. Soda Lake R/A C-5-30-46-23	5-30-46-23W3	1873	--	--	--	--	1956 (E)	1995	2032	N.P.
Rich. Jack Fot Lake No. 1	7-21- 8-24W3	3886	--	6034	6125	N.P.	N.P.	N.P.	N.P.	N.P.
H. P. Eatonia No. 1.	4-32-26-24W3	2444	--	3412	3514	3603	3852	4398	4442	4544
Coleville Unit No. 7-19-31-24	7-19-31-24W3	2217	2870	2913	3011	N.P.	N.P.	N.P.	N.P.	N.P.
Canso Buffalo Coulee No. 3	6-32-32-24W3	2347	2867	2908	3020 (approx)	N.P.	N.P.	N.P.	N.P.	N.P.
Spooner Street Lake No. 10-32	10-32-33-24W3	2275	2709	2752	2885	N.P.	N.P.	N.P.	N.P.	N.P.

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Woods Para. Shallow Lake R/A N Bdy 20-35-24	4-29-35-24W3	2219	—	2516	2628	N.P.	N.P.	N.P.	N.P.	N.P.
Woods Para. Luseland R/A E. Bdy 12-36-25	13- 7-36-24W3	2263	—	2563	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
Woods Para. Luseland R/A W. Bdy 32-36-24	13-32-36-24W3	2286	—	2520	2623	2728	N.P.	N.P.	N.P.	N.P.
Ceepee Reward 4-28	4-28-38-24W3	2282	—	2403	2483	2582	2770	3264	3296	3419
H.B.Bata Denzil No. 4	16- 6-39-24W3	2268	—	—	2445 (E)	2537	N.P.	N.P.	N.P.	N.P.
Trans-Era Unity No. 1	16-11-39-24W3	2250	—	2368 (E)	2387	2483	2662	3172	3200	3328
W. Pot. Superior Bata No. 2	2- 1-41-24W3	2049	—	—	—	2193 (E)	2341	2804	2820	2935
W. Pot. Bata 1-13	1-13-41-24W3	1932	—	—	—	2043 (E)	2172	2649	2675	2785
Bata No. 15	12-13-41-24W3	1940	—	—	—	2080 (E)	N.P.	N.P.	N.P.	N.P.
Verbata No. 2	7-24-41-24W3	1948	—	—	—	2084 (E)	2140	2632	2645	2778
Bata No. 23	15-12-42-24W3	1931	—	—	—	2018 (E)	2078	2560	2577	2696
Shell Alb. Arena A-6-30	6-30- 1-25W3	2940	5258	5282	5362	5390	5611	N.P.	N.P.	N.P.
Imp. Cal. Robsart 1-1	1- 1- 5-25W3	3157	5400	5448	5530	5553	5769	6218	6248	6318
Trans Empire Maple Creek No. 1	16-20- 9-25W3	3556	5587	5607	5712	5732	5962	6367	6403	6503
Canso Allenbee Keno and Assoc. No. 1	13- 7-14-25W3	2395	4200	4240	4338	4356	4609	5021	5055	5160

Well Name	Location	Kelly Bushing Elevation (feet above sea level)	Torquay Formation	Birdbear Formation		Duperow Formation				Top of Souris River Formation (feet below K.B.)
			Top of Unit 2 (feet below K.B.)	Top of Upper Member (feet below K.B.)	Top of Lower Member (feet below K.B.)	Top of Seward Member (feet below K.B.)	Top of Wymark Member (feet below K.B.)	Top of Elstow Member (feet below K.B.)	Top of Saskatoon Member (feet below K.B)	
Saskoil Leader No. 1	9-15-20-25W3	2287	3738	3752	3880	3897	4126	N.P.	N.P.	N.P.
Canso Oil Somerset Superb 16-29	16-29-33-25W3	2394	2870	2920	3032	3108	N.P.	N.P.	N.P.	N.P.
Canso Oil Patrick 3-30	3-30-34-25W3	2434	2855	2880	3010	3082	N.P.	N.P.	N.P.	N.P.
H.B. Canso Denzil No. 3	16-22-38-25W3	2274	--	2417	2513	2606	N.P.	N.P.	N.P.	N.P.
H.B. Canso Denzil No. 5	2- 2-39-25W3	2255	--	2412 (E)	2470	2563	N.P.	N.P.	N.P.	N.P.
Sup. Bata Rutland No. 1	13-11-41-25W3	2113	--	--	--	--	2480 (E)	2960	2976	3095
Oregon Petroleums O C No. 2	16-25-42-25W3	2151	--	--	--	--	2298 (E)	2770	2787	2904
H. J. McLaren No. 1	4- 6-50-25W3	2105	--	--	--	--	--	--	2202 (E)	N.P.
H. J. McLaren No. 3	9-16-50-25W3	2007	--	--	--	--	--	--	2061 (E)	N.P.
Imp. Canso Fed. Co-op Cal. Battle Creek 4-31-3-26	4-31- 3-26W3	3072	5138	5151	5235	5258	5475	5847	5875	5976
Cal. Can. Dev. Imp. Jackpot Lake 11-23	11-23- 8-26W3	3788	5822	5842	5940	5960	6188	N.P.	N.P.	N.P.
P. H. Cathy No. 1	11-17-30-26W3	2325	3122	3154	3267	3345	N.P.	N.P.	N.P.	N.P.
H.P. Whiteside No. 11-22	11-22-30-26W3	2375	3108	3135	3256 (approx)	N.P.	N.P.	N.P.	N.P.	N.P.
Alb. Crown 2-22-35-26	2-22-35-26W3	2399	--	2810	2919	3004	N.P.	N.P.	N.P.	N.P.
Cal. et al Hearts Hill No. 13-36	13-36-35-26W3	2353	--	2735	2840	2929	3115	3674	3708	3830

Well Name	Location	Kelly Bushing Elevation (feet above sea level)	Torquay Formation: Top of Unit 2 (feet below K.B.)	Birdbear Formation: Top of Upper Member (feet below K.B.)	Birdbear Formation: Top of Lower Member (feet below K.B.)	Duperow Formation: Top of Seward Member (feet below K.B.)	Duperow Formation: Top of Wymark Member (feet below K.B.)	Duperow Formation: Top of Elstow Member (feet below K.B.)	Duperow Formation: Top of Saskatoon Member (feet below K.B)	Top of Souris River Formation (feet below K.B.)
H.B. Canso Denzil No. 2	16-22-38-26W3	2296	--	2622	2690	2786	N.P.	N.P.	N.P.	N.P.
H.B. Canso Denzil No. 6	13-24-39-26W3	2211	--	2370 (E	2377	2465	N.P.	N.P.	N.P.	N.P.
C.S. No. 29	5-10-50-26W3	2145	--	--	--	--	--	--	2290 (E)	N.P.
H. J. Greenstreet No. 1	9-28-51-26W3	1901	--	--	--	--	--	--	1881 (E)	N.P.
Husky Greenstreet No. 4	9-34-51-26W3	1962	--	--	--	--	--	--	1976 (E)	N.P.
Calstan Fort Pitt 1-25	1-25-54-26W3	2189	--	--	--	--	2122 (E	--	--	2328
Nuco Calstan North Fort Pitt 4-23	4-23-55-26W3	2284	--	--	--	--	--	--	2244 (E)	2337
Imp. Fed. Co-op Cal. Som. Senate 14-7-5-27	14- 7- 5-27W3	3194	5278	5295	5377	5398	5637	6020	6050	6129
B.A.Hstd. Alscope Wilnichenko 2-12	2-12-13-27W3	2480	4300	4326	4423	4442	4699	5110	5145	5246
B.A.Arndt 15-15	15-15-14-27W3	2406	4140	4184	4277	4297	4545	4960	5006	5108
New Sprig Pure Fox Valley 16-9-16-27	16- 9-16-27W3	2567	--	4205	4344	4370	N.P.	N.P.	N.P.	N.P.
Hoosier Unit No. 1-10-31-27	1-10-31-27W3	2385	--	3000	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
Altair Harrington Marsh Antelope 6-3-32-27	6- 3-32-27W3	2310	--	2965	3010	N.P.	N.P.	N.P.	N.P.	N.P.
Cdn. Seab. Canso Fusilier No. 7-1	7- 1-33-27W3	2403	--	2983	3076	N.P.	N.P.	N.P.	N.P.	N.P.
Cdn Seab. Canso Fusilier No. 10-33	10-33-33-27W3	2350	--	2926	3033	3106	N.P.	N.P.	N.P.	N.P.

Well Name	Location	Kelly Bushing Elevation (feet above sea level)	Torquay Formation	Birdbear Formation		Duperow Formation				
			Top of Unit 2 (feet below K.B.)	Top of Upper Member (feet below K.B.)	Top of Lower Member (feet below K.B.)	Top of Seward Member (feet below K.B.)	Top of Wymark Member (feet below K.B.)	Top of Elstow Member (feet below K.B.)	Top of Saskatoon Member (feet below K.B)	Top of Souris River Formation (feet below K.B.)
Roy. Alb. Denzil No. 1	15-21-37-27W3	2465	—	2730	2859	2967	3200	3662	3686	3789
H.B. Canso Denzil No. 1	16-22-38-27W3	2452	—	—	2769 (E)	2845	N.P.	N.P.	N.P.	N.P.
Fargo Epping No. 11-18	11-18-47-27W3	2088	—	—	—	—	2240	—	—	2595
H.N.B. No. 1	8-10-49-27W3	2086	—	—	—	—	2204 (E)	—	—	2412
Husky Dulwich No. 1	1-17-49-27W3	2100	—	—	—	—	2240 (E)	N.P.	N.P.	N.P.
Husky Hill Valley No. 1	9- 6-53-27W3	1901	—	—	—	—	1895 (E)	N.P.	N.P.	N.P.
Nuco-Calstan-S.W. Fort Pitt No. 4-22	4-22-53-27W3	1914	—	—	—	—	1822 (E)	—	—	1998
Shell Govenlock No. 1	2- 7- 1-28W3	2763	4942	4977	5055	5074	5296	5643	5668	5745
Shell Barclay Supreme No. 1	7- 2- 2-28W3	3044	5224	5238	5327	5352	5548	5933	5950	6016
M.O. North Richmound 31-1	1-31-18-28W3	2521	4003	4029	4145	4179	4409	4878	4922	5032
P. H. Compeer No. 1	13-18-33-28W3	2340	—	2946	3012	N.P.	N.P.	N.P.	N.P.	N.P.
Bata Provost No. 1	4- 5-35-28W3	2314	—	2875	2951	3030	N.P.	N.P.	N.P.	N.P.
Bata Sun.	4-16-35-28W3	2290	—	2828	2886	2974	3242	3730	3760	3884
Bata Sun.	8- 4-37-28W3	2186	—	2605	2697	2768	3014	3493	3524	3650
Sup. Dempsey Macklin No. 2	4-36-38-28W3	2242	—	—	2508 (E)	2597	2872	3357	3387	3518
Sup. Dempsey Macklin No. 1	5-15-39-28W3	2252	—	—	2624 (E)	2654	2875	3352	3387	3514
Shell Senlac A-4-28	4-28-41-28W3	2152	—	—	—	—	2543 (E)	N.P.	N.P.	N.P.

Well Name	Location	Kelly Bushing Elevation (feet above sea level)	Torquay Formation	Birdbear Formation		Duperow Formation					
			Top of Unit 2 (feet below K.B.)	Top of Upper Member (feet below K.B.)	Top of Lower Member (feet below K.B.)	Top of Seward Member (feet below K.B.)	Top of Wymark Member (feet below K.B.)	Top of Elstow Member (feet below K.B.)	Top of Saskatoon Member (feet below K.B)	Top of Souris River Formation (feet below K.B.)
Sup. Bata et al Manito No. 2	6-34-42-28W3	2019	—	—	—	—	2356 (E)	2796	2808	2960
Bata No. 28	13-22-43-28W3	2135	—	—	—	—	2478 (E)	N.P.	N.P.	N.P.
Tidal Kodiak LDC Harlan D 6-24	6-24-53-28W3	1896	—	—	—	—	1877 (E)	N.P.	N.P.	N.P.
Shell Alb. Govenlock No.2	16- 3- 1-29W3	2845	4954	4994	5060	5083	5290	N.P.	N.P.	N.P.
Inter City Burstall No. 1	10-21-20-29W3	2366	—	3780	3894	3952	N.P.	N.P.	N.P.	N.P.
Inter City Burstall No. 2	1- 1-21-29W3	2388	—	3769	3882	3943	N.P.	N.P.	N.P.	N.P.
M.O. Cypress Lake X-10-2	10- 2- 5-30W3	3343	5277	5293	5378	5396	5599	6012	6028	6119

Well Name	Land Location	Kelly Bushing Elevation (feet above sea level)	Top of Crow Foot Formation (feet below K.B.)	Top of Birdbear Equivalent (feet below K.B.)	Top of Upper Ireton Member (feet below K.B.)	Top of Peechee Member (feet below K.B.)	Top of Seward Equivalent (feet below K.B.)	Top of Wymark Equivalent (feet below K.B.)	Top of Elstow Equivalent (feet below K.B.)	Top of Saskatoon Equivalent (feet below K.B.)	Top of Beaverhill Lake Formation (feet below K.B.)	Top of Souris River Formation (feet below K.B.)
Allenbee Peak & Assoc. Canso Schuler No. 1	2-22-15- 1W4	2681	—	4326	4426	—	4450	4750	5135	5178	—	5266
B.A. et al Canmor 6-9-31-1	6- 9-31- 1W4	2409	—	3156	3270	3330	—	3605	4180	4214	4266	4331
Texaco Compeer No. A1-22	1-22-33- 1W4	2338	—	2982	3080	3149	—	3365	3927	3947	4035	N.P.
Texaco Altario No. B-2-4	2- 4-34- 1W4	2389	—	3010	3108	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
Texaco Altario No. 15-15	15-15-34- 1W4	2400	—	3012	3110	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
Sage Meridian Century Kenare Rosenheim No. 1	11-20-37- 1W4	2277	—	—	—	—	—	3030 (E)	3592	3623	3681	3752
Lloyd. Dev. Disposal Well No. 1	8- 6-50- 1W4	2207	—	—	—	—	—	2369 (E)	2418	2438	2534	2632
Socony Wildhorse No. 1	15-36- 1- 2W4	2875	—	4783	4859	—	4878	5073	5450	5466	—	5570
Anglo Pacific et al N.N.G.P. Co. Bain No. 10-20	10-20- 2- 2W4	2964	—	4782	4853	—	4878	5061	5488	5502	—	5531
Widney Ward No. 1	7-30-33- 2W4	2382	—	3053	3160	3225	—	3366	4020	4060	N.P.	N.P.
Imperial Eyehill No. 1	13-36-35- 2W4	2667	—	3204	3310	3386	—	3550	4113	4147	4197	4267
Petromino Ribstone No. 1	8-31-43- 2W4	2056	—	—	—	—	—	2353 (E)	2867	2900	2050	3038
Merrill Kirriemuir No. 7-16	7-16-34- 3W4	2360	—	2995	3058	3115	—	3408	3982	4010	N.P.	N.P.
Allenbee Peak & Assoc. Petro. Pemukan No. 1	10-21-35- 3W4	2519	—	3151	3210	3266	—	3494	4062	4103	4159	(Approx) 4221
Imperial Provost No. 2	1-33-37- 3W4	2420	—	—	—	—	—	3270	3815	3847	3900	3977
Rich. Shell Rapid Narrows 11-20	11-20-16- 4W4	2472	—	3994	4070	—	4052	4404	4810	4848	4890	4948

Well Name	Land Location	Kelly Bushing Elevation (feet above sea level)	Top of Crow Foot Formation (feet below K.B.)	Top of Birdbear Equivalent (feet below K.B.)	Top of Upper Ireton Member (feet below K.B.)	Top of Peechee Member (feet below K.B.)	Top of Seward Equivalent (feet below K.B.)	Top of Wymark Equivalent (feet below K.B.)	Top of Elstow Equivalent (feet below K.B.)	Top of Saskatoon Equivalent (feet below K.B.)	Top of Beaverhill Lake Formation (feet below K.B.)	Top of Souris River Formation (feet below K.B.)
Asher Sapphire Misty Lake No. 16-1	16- 1-33- 4W4	2304	—	3007	3127	3175	—	3469	N.P.	N.P.	N.P.	N.P.
Calstan Dunmore Prov. 33-2-11-5	7- 2-11- 5W4	2776	—	4352	4422	—	4450	N.P.	N.P.	N.P.	N.P.	N.P.
H. B. Sparky No. 1	4-12-29- 5W4	2613	—	3540	3668	3750	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
Skyline Mic-Mac & Assoc. Monitor No. 1	6-29-33- 5W4	2586	—	3332	3454	3522	—	—	4392	—	N.P.	N.P.
B.A. Stewart Provost 10-13-40-5	10-13-40- 5W4	2246	—	—	—	—	2642 (E)	2833	3511	3533	3610	3692
T. P. C. & O. Comrey No. 11-32	11-32- 2- 6W4	3282	—	4655	4720	—	4750	4917	5378	5395	5447	5504
Cities Service Alkali Creek 11-12	11-12-24- 6W4	2599	—	3833	3947	4040	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
British Dominion Pakowki No. 1	15-22- 6- 7W4	2972	—	4452	4507	—	4532	N.P.	N.P.	N.P.	N.P.	N.P.
Home Peigan Creek 6-29-7-7	6-29- 7- 7W4	2835	—	4285	4352	—	4385	4580	5058	5081	5115	5163
High Crest et al Atlee No. 2	15-16-21- 7W4	2669	—	4020	4142	—	4198	N.P.	N.P.	N.P.	N.P.	N.P.
Western Chinook No. 11-8	11- 8-29- 7W4	2585	—	3639	3746	3816	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
C. S. Western Leaseholds Chinook 21-4	4-21-30- 7W4	2524	—	3538	3643	3717	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
Dome J. V. Consort 13-9	13- 9-37- 7W4	2691	—	3480 (E)	3496	3580	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
B. A. HG S3 Hughenden 9-33-40-7	9-33-40- 7W4	2279	—	—	2942 (E)	2950	—	—	3688	3713	3797	3870

Well Name	Land Location	Kelly Bushing Elevation (feet above sea level)	Top of Crow Foot Formation (feet below K.B.)	Top of Birdbear Equivalent (feet below K.B.)	Top of Upper Ireton Member (feet below K.B.)	Top of Peechee Member (feet below K.B.)	Top of Seward Equivalent (feet below K.B.)	Top of Wymark Equivalent (feet below K.B.)	Top of Elstow Equivalent (feet below K.B.)	Top of Saskatoon Equivalent (feet below K.B.)	Top of Beaverhill Lake Formation (feet below K.B.)	Top of Souris River Formation (feet below K.B.)
Wainwright Prod. & Ref. D.W. No. 1	15-36-44- 7W4	2216	—	2331 (E)	2395	2475	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
Calstan Vermillion 13-36-51-7	13-36-51- 7W4	2064	—	--	—	—	—	2190 (E)	2530	2554	2652	2727
Home CMG Black Butte 10-7	10- 7- 1- 8W4	3553	—	4292	4348	—	4370	4538	4987	5003	5032	5074
Home CMG Pendor 7-17	7-17- 3- 8W4	2995	—	4190	4254	—	4277	4448	4910	4940	4971	5018
Mid-Cont. Brit. Dom Etzikom No. 1	3-29- 6- 8W4	2800	—	4221	4270	—	4308	N.P.	N.P.	N.P.	N.P.	N.P.
Western Mayrath Jenner 18-4	4-18-21- 8W4	2522	—	3983	4100	—	4153	N.P.	N.P.	N.P.	N.P.	N.P.
Anglo Heathdale No. 1	14- 5-27- 8W4	2646	—	3917	4014	4093	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
Mac-Sil. Co. Leaseholds H.B. Amisk No. 1	8-26-42- 8W4	2371	—	2736	2838	2917	—	—	3680	3710	3800	(Approx.) 3870
Abram Morris Lloyd-Lloyd West Vermillion 11-2	11- 2-51- 8W4	2050	—	—	—	—	--	2295 (E)	2687	2725	2813	2888
Home CMG Pendor 6-6-4-9	6- 6- 4- 9W4	3063	—	4214	4282	—	4307	4488	4947	4976	5014	5058
Home et al Suffield 3-27	3-27-13- 9W4	2531	—	4038	4125	4169	—	4365	4894	4920	4968	5025
•Can. Sup. Hardisty 7-32-43-9	7-32-43- 9W4	2235	—	2672	2748	2820						
Imperial Irma No. 1	6-14-46- 9W4	2863	—	—	—	—	—	2613 (E)	3449	3469	3567	3642
Home B.A. Granlea 10-29	10-29- 8-10W4	2785	--	4168	4241	4280	—	4439	4977	5008	5048	5096
Hatd. Cal. Hamilton Lake 8-15	8-15-35-10W4	2537	—	3610	3700	3775	—	—	4625	4650	4720	4790
Imperial Hardisty 16-20-41-10	16-20-41-10W4	2314	—	3022	3130	3212	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.

Well Name	Land Location	Kelly Bushing Elevation (feet above sea level)	Top of Crow Foot Formation (feet below K.B.)	Top of Birdbear Equivalent (feet below K.B.)	Top of Upper Ireton Member (feet below K.B.)	Top of Peechee Member (feet below K.B.)	Top of Seward Equivalent (feet below K.B.)	Top of Wymark Equivalent (feet below K.B.)	Top of Elstow Equivalent (feet below K.B.)	Top of Saskatoon Equivalent (feet below K.B.)	Top of Beaverhill Lake Formation (feet below K.B.)	Top of Souris River Formation (feet below K.B.)
Home Pacific Knappen 16-29-1-11	16-29- 1-11W4	3225	—	3764	3819	—	3845	4030	4472	4489	4522	4570
Tex. New Sup. Alderson C.P.R. A-7-14	7-14-15-11W4	2459	—	4016	4100	4143	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
Baily Anson Monogran No. 1	14-16-16-11W4	2521	—	4088	4180	4230	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
C.P.O.G. Princess 10-4-19-11	10- 4-19-11W4	2536	—	4139	4242	4270	—	4511	5037	5067	5115	5176
Flock C.P.R. Denhart 2-14-11	14-11-20-11W4	2515	—	4002	4103	4141	—	4389	4933	4944	5007	5073
Home Imp. Foremost 9-23-7-12	9-23- 7-12W4	2825	—	4166	4246	4285	—	4475	4949	4979	5025	5075
B. A. Grand Forks 12-14-12-12	12-14-12-12W4	2488	—	4050	4122	4158	—	4379	4887	4915	4960	5015
Caletan Sunnybrook 9-23	9-23-26-12W4	2504	—	4090	4195	4240	—	—	—	—	5187	5241
Calatan Sunnybrook 11-24	11-24-26-12W4	2491	—	4085	4176	4230	—	—	—	—	5172	5240
Canso Coronation 11-11-35-12	11-11-35-12W4	2638	—	3912	3997	4069	—	—	—	—	5040	5111
Alb. W. Prairie Fina Goose Lake No. 1	13-28-41-12W4	2286	—	3208	3316	3390	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
•Calstan Sedgewick 8-28	8-28-43-12W4	2310	—	2957	3020	3075	—	—	—	—	4148	—
Pac. H.B. Lucky Strike 13-8-4-13	13- 8- 4-13W4	3046	—	4080	4150	4182	—	4360	4820	4850	4892	4935
Home Yellow Lake 1-36-9-13	1-36- 9- 13W4	2679	—	4191	4270	4314	—	4505	4987	5013	5058	5112
Imp. Grassy Lake No. 3	2-35-10-13W4	2676	—	4198	4268	4334	—	4527	4960	4993	5039	5110
Home High Crest Steveville No. 1	5-28-22-13W4	2567	—	4110	4198	4240	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.

Well Name	Land Location	Kelly Bushing Elevation (feet above sea level)	Top of Crow Foot Formation (feet below K.B.)	Top of Birdbear Equivalent (feet below K.B.)	Top of Upper Ireton Member (feet below K.B.)	Top of Peechee Member (feet below K.B.)	Top of Seward Equivalent (feet below K.B.)	Top of Wymark Equivalent (feet below K.B.)	Top of Elstow Equivalent (feet below K.B.)	Top of Saskatoon Equivalent (feet below K.B.)	Top of Beaverhill Lake Formation (feet below K.B.)	Top of Souris River Formation (feet below K.B.)
Old Smoky Lawrence No. 1	10-21-30-13W4	2748	—	4480	4537	4616	—	—	N.P.	N.P.	N.P.	N.P.
•Rich. Schneider Lake 6-24-41-13	6-24-41-13W4	2302	—		3399	3470						
•Rich. Calstan Lawn H 12-13-42-13	12-13-42-13W4	2289	—		3330	3408						
•McC. & Col. VCA Killan 15-16-44-13	15-16-44-13W4	2242		3143	3216						4185	
B.A. - H.B. Verdigris 7-26	7-26- 3-14W4	3082	—	4019	4087	4118	—	4296	4770	4801	4891	4885
Imp. Calstan Lake Newell 5-1-17-14	5- 1-17-14W4	2466	—	4200	4299	4330	—	4590	—	—	5200	5270
Amer. Stan. Crown BF 21A-23	14-23-26-14W4	2530	—	4410	4500	4545	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
•Banff et al Galahad 10-32-40-14	10-32-40-14W4	2355		3582	3730	3815						
•H.B. et al Forestburg No. 1	11-32-41-14W4	2331			3712	3809						
•H.B. et al Forestburg 11-33-41-14	11-33-41-14W4	2315		3430	3530	3602						
•R.O. Pleasington 10-36-42-14	10-36-42-14W4	2268		3375	3455	3753						
•M & C Killan West 16-2-44-14	16- 2-44-14W4	2266			3408							
Smith C.P.R. No. 1	6- 4-20-15W4	2538	—	4520	4606	4655	—	4941	—	—	5529	5610
Hanna Syndicate No. 1	14-22-32-15W4	2746	—	4640	4720	4798	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
•Zapata et al Forestburg 6-35-40-15	6-35-40-15W4	2370		3722	3765	3846					4870	

Well Name	Land Location	Kelly Bushing Elevation (feet above sea level)	Top of Crow Foot Formation (feet below K.B.)	Top of Birdbear Equivalent (feet below K.B.)	Top of Upper Ireton Member (feet below K.B.)	Top of Peechee Member (feet below K.B.)	Top of Seward Equivalent (feet below K.B.)	Top of Wymark Equivalent (feet below K.B.)	Top of Elstow Equivalent (feet below K.B.)	Top of Saskatoon Equivalent (feet below K.B.)	Top of Beaverhill Lake Formation (feet below K.B.)	Top of Souris River Formation (feet below K.B.)
Zapata *et al* Forestburg 7-9-41-15	7- 9-41-15W4	2367	—	3825	3956	—	—	—	—	—	4915	4973
•Triad Daysland 1-28-43-15	1-28-43-15W4	2334		3450	3725							
K.O.-C.P.R. Warner South 10-17	10-17- 2-16W4	3455	—	4216	4266	4296	—	—	—	—	4970	5003
Sunderland Warner No. 1	13-20- 4-16W4	3362	—	4630	4694	4725	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
Honolulu Taber 6-25-10-6	6-25-10-16W4	2593	—	4362	4439	4485	—	—	—	—	5270	5325
Imp. Golden Hill 12-2	12- 2-30-16W4	3049	—	5160	5265	5327	—	—	—	—	6234	6295
•Scurry Merit Halkirk 13-11-38-16	13-11-38-16W4	2750		4402	4579	4638						
•Honolulu Daysland	10-30-45-16W4	2314			3756							
Texaco Enchant No. 1	3-34-13-17W4	2669	—	4680	4730	4782	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
Baysel *et al* Eyremore 10-21-19-17	10-21-19-17W4	2657	—	4875	4973	5015	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
Kewanee E. Cessford 10-33-27-17	10-33-27-17W4	2774	5094	5135	5215	5280	—	—	—	—	6161	6222
•Homestead Westates Delia 11-9-29-17	11- 9-29-17W4	2099			5580							
•C.D.R. Handhills 1-33-29-17	1-33-29-17W4	3492	5805	5888	6000							
•C.D.R. Handhills 11-12-30-17	11-12-30-17W4	3538	—	5783	5863	5934						

Well Name	Land Location	Kelly Bushing Elevation (feet above sea level)	Top of Crow Foot Formation (feet below K.B.)	Top of Birdbear Equivalent (feet below K.B.)	Top of Upper Ireton Member (feet below K.B.)	Top of Peechee Member (feet below K.B.)	Top of Seward Equivalent (feet below K.B.)	Top of Wymark Equivalent (feet below K.B.)	Top of Elstow Equivalent (feet below K.B.)	Top of Saskatoon Equivalent (feet below K.B.)	Top of Beaverhill Lake Formation (feet below K.B.)	Top of Souris River Formation (feet below K.B.)
•Phillips Handhills 10-3-32-17	10- 3-32-17W4	2785	4984	5075	5156	5214						
Western Byemoore 34-8	8-34-34-17W4	2795	4830	4918	5012	5068	—	—	—	—	5980	6033
Imp. Can. Sup. Leo 8-28-35-17	8-28-35-17W4	2759	4786	4867	4938	4995	—	—	—	—	5951	6006
•W.R. Can. Sup. C. & E. Gadsby 11-34-38-17	11-34-38-17W4	2635			4705							
Bowlf No. 1	9-30-45-17W4	2334	3756	—	3911	N.P.	—	—	—	—	N.P.	N.P.
Grt. Plains Triad Crowfoot 2-10	2-10-20-18W4	2704	—	5075	5185	5222	—	—	—	—	N.P.	N.P.
H.B. Pan Am. Wintering Hills 10-21	10-21-24-18W4	2931	—	5418	5508	5572	—	—	—	—	6430	6497
•Ambase. E. Drumheller 16-7-29-18	16- 7-29-18W4	2757	5252	5312	5412	5515						
•Texaco Delia 4-29-31-18W4	4-29-31-18W4	2847	5267	5358	5455	5491						
•Dome United Prod. Delia 1-6-32-18	1- 6-32-18W4	2833	5265	5359	5450	5498						
•Imp. Can. Sup. Gough Lake 4-10-35-18	4-10-35-18W4	2739			5064	5123						
•W.R. Security Gough 9-23-35-18	9-23-35-18W4	2715			4940	4980						
B.A. Cities Service Hackett No. 1	13-15-36-18W4	2755	4972	5065	5145	—	—	—	—	—	N.P.	N.P.
•W.R. Can. Sup. Hack 10-21-36-18	10-21-36-18W4	2756	4984	5067	5167	—						

Well Name	Land Location	Kelly Bushing Elevation (feet above sea level)	Top of Crow Foot Formation (feet below K.B.)	Top of Birdbear Equivalent (feet below K.B.)	Top of Upper Ireton Member (feet below K.B.)	Top of Peechee Member (feet below K.B.)	Top of Seward Equivalent (feet below K.B.)	Top of Wymark Equivalent (feet below K.B.)	Top of Elstow Equivalent (feet below K.B.)	Top of Saskatoon Equivalent (feet below K.B.)	Top of Beaverhill Lake Formation (feet below K.B.)	Top of Souris River Formation (feet below K.B.)
Rio Bravo Liebing 8-24	8-24-38-18W4	2713	4740	4835	4919	—	—	—	—	—	N.P.	N.P.
•Supertest W.R. Drumheller 14-9-29-19	14- 9-29-19W4	2701	5339	5383	5503	5555						
•Ambas E. Drumheller 9-13-29-19	9-13-29-19W4	2786	5307	5365	5490	5560						
•Altair Drumheller 1-16-29-19	1-16-29-19W4	2705	5325	—	5510	5582						
•Husky Dome Colorado Drumheller 2-9-30-19	2- 9-30-19W4	2679	5283	5337	5469	5474						
Dome Soc. Michichi 11-15	11-15-30-19W4	2764	5310	5400	5500	5560	—	—	—	—	6457	6493
•Honolulu B. A. M.O. Rowley 16-20	16-20-32-19W4	2882	5536	5625	5726	5810						
C.D.R. McKee Lake 4-6-33-19	4- 6-33-19W4	2810	5508	5600	5700	N.P.	—	—	—	—	N.P.	N.P.
•C.D.R. et al Fenn Big Valley 2-30-35-19	2-30-35-19W4	2793	5350	5419	5522	5927	—	—	—	—	6420	
Pacific Western McGregor Lake No. 1	13- 7-17-20W4	3017	—	5820	5931	5961	—	—	—	—	N.P.	N.P.
•W.R. CWNG Drumheller 10-12-29-20	10-12-29-20W4	2566	5294	5326	5447	5510						
•Leduc Calmar & Assoc. Drumheller #2	12-33-29-20W4	2652	5535	5556	5662	5681						
B.A. McConkey Munson 7-34	7-34-30-20W4	2712	—	5440	5550	5582	—	—	—	—	6580	6635
•Cree et al Drumheller 2-12-30-20	2-12-30-20W4	2700			5504	5509						

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B.A. Morrin 7-3-31-20	7- 3-31-20W4	2719	--	5506	5635	5688	—	—	—	—	6600	6651
•Amerada Cr. BA Morrin 5-34-31-20	5-34-31-20W4	2730	5566	5618	5740	—	—	—	—	—	6577	
•Mic Mac Calstan McKee 11-36-32-20	11-36-32-20W4	2833	5265	5359	5450	5498						
Gulf Swanson #10	10-16-38-20W4	2715	—	—	5550	5582	—	—	—	—	6335	6455
National Northland Regency No. 1	8- 7- 1-21W4	4307	—	6564	6612	6636	—	—	—	—	—	7371
Fina Triad Lake McGregor 10-16	10-16-15-21W4	2878	—	5810	5860	5889	—	—	—	—	N.P.	N.P.
•Ohio Kirkpatrick 4-28-29-21	4-28-29-21W4	2700	5733	5754	5866	5908						
•Grt. Plains et al Kirkpatrick 11-32-29-21	11-32-29-21W4	2662	5676	5700	5802	5850						
•Altana Canso Drumheller West 8-34-29-21	8-34-29-21W4	2294	—	5211	5298	5320						
•Altana et al Kirkpatrick 2-4-30-21	2- 4-30-21W4	2303	5236	5260	5360	5406	—	—	—	—	6420	
•Imp. Morrin 16-5-30-21	16- 5-30-21W4	2666	5736	5763	5894	5986						
•Imp. H.B. Morrin 4-26-30-21	4-26-30-21W4	2680	5708	5750	5884	—						
•Murphy et al Rowley 10-36-31-21	10-36-31-21W4	2800	5773	5825	5920	—						
Forgotson Burk Rowley 10-34	10-34-32-21W4	3-16	—	—	6165	—	--	—	—	—	7028	7093
Int. Blood Indian No. 1	2- 7- 8-22W4	3112	--	6657	6710	6730	—	—	—	—	—	7492

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•Calvan *et al* Carbon 11-9-29-22	11- 9-29-22W4	1980	—	6041	6146	6169						
•Amerada *et al* Carbon 10-25-29-22	10-25-29-22W4	2777	—	5916	5990	6020						
•Shell Carbon B-7-29	7-29-29-22W4	2754	6030	6057	6147	6190						
•B.A. C.P.R. Huxley 2-33-33-22	2-33-33-22W4	2778			6170							
Socony Jefferson 18-14	18-14- 2-23W4	4107	—	8230	8273	8290	—	—	—	—	N.P.	N.P.
Imp. Monarch 13-35	13-35- 8-23W4	3091	—	6450	6495	6560	—	—	—	—	N.P.	N.P.
Imp. Nobleford 15-1	15- 1-11-23W4	3286	—	7055	7097	7155	—	—	—	—	N.P.	N.P.
Imp. Carmangay 4-17	4-17-13-23W4	3152	—	7202	7250	7292	—	—	—	—	8088	8145
•CWNG Carbon 10-24-29-23	10-24-29-23W4	2750	6138	6158	6252	6312						
•U.B. Union H. O. N Carbon 10-5	10- 5-30-23W4	3050			6830							
•Grt. Plains Choqua Three Hills 14-19-30-23	14-19-30-23W4	2813			6590							
•M.O. Equity South 14-1-31-23	14- 1-31-23W4	3027		6684								
•Grt. Plains Choqua Three Hills 5-10-31-23	5-10-31-23W4	2964	6573	6620	6740							
Husky Phillips Wican No. 1	8-13-16-24W4	3414	—	7223	7298	7335	—	—	—	—	—	8163

Well Name	Location	Kelly Bushing Elevation (feet above sea level)	Torquay Formation: Top of Unit 2 (feet below K.B.)	Birdbear Formation: Top of Upper Member (feet below K.B.)	Birdbear Formation: Top of Lower Member (feet below K.B.)	Duperow Formation: Top of Seward Member (feet below K.B.)	Duperow Formation: Top of Wymark Member (feet below K.B.)	Duperow Formation: Top of Elstow Member (feet below K.B.)	Duperow Formation: Top of Saskatoon Member (feet below K.B)	Top of Souris River Formation (feet below K.B.)
Schoonmaker #1 Stephen	C-NW-SE-12-20N-1E	3781	—	2590	2612	2648	2800	3065	3090	3178
Continental #1 State	2-25N-1E	3474	—	2860	—	2895	3095	—	—	3370
Montalban #1 Bakken	C-NW-SW-22-26N-1E	3466	—	3136	3160	3186	3352	3738	3747	3803
Texaco #1 Thisted	C-NE-NE-17-36N-1E	3756	—	3305	3350	3367	3527	3960	3980	4047
United #1 Good	18-23N-3E	3642	—	2943	2970	3000	3132	3477	3494	3587
General Pete #8-11-P Kaun	11-27N-3E	3287	—	3263	3305	3326	3458	—	—	3798
Montana No. 1 Stein	12-33N-3E	3549	—	3735	3768 (approx)	—	—	—	—	—
Anschutz No. 1 Morris	15-36N-3E	4345	—	4068	4132	4152	4262	4709	4719	4809
Texas No. 2 Laas	C-NW-NE-SW-14-33N-4E	3400 (approx)	—	3524	3570	3594	?	?	?	?
Anaconda No. 4 Blair Union Bank	15-34N-4E	3565	—	3752	3787	3827	—	—	—	—
Union Mahoney Whitlash	22-37N-4E	3939	—	3750	3808	3823	3938	—	—	—
Nairn-Hanley-Cole No. 1 Onstead	SE-SE-SE-5-25N-5E	3205	—	3281	3308	3342	3484	3819	3844	3936
L.B. O'Neil No. 1 Brown	29-30N-5E	2873	—	3420	3462	3485	3652	4041	4058	4110
Phillips No. 1 Miller	15-37N-5E	3466	—	3792	3840	3876	4065	4488	4508	4560
Gulf No. 1 Chris Nelson	SE-NE-12-24N-6E	3040	—	3133	—	3182	?	?	?	3603
Amerada No. 1 U.S.A. Paul	11-29N-6E	3045	—	3852	3876	3897	4102	—	—	—
Texas No. 1 Colbry	13-36N-6E	3468	—	3930	4003	4023	4200	4595	4611	4670

Well Name	Location	Kelly Bushing Elevation (feet above sea level)	Torquay Formation	Birdbear Formation		Duperow Formation				
			Top of Unit 2 (feet below K.B.)	Top of Upper Member (feet below K.B.)	Top of Lower Member (feet below K.B.)	Top of Seward Member (feet below K.B.)	Top of Wymark Member (feet below K.B.)	Top of Elstow Member (feet below K.B.)	Top of Saskatoon Member (feet below K.B)	Top of Souris River Formation (feet below K.B.)
Texas No. 1 Sorrell Gov't	C-NE-NW-29-36N-6E	3500 (approx)	—	3955	4002	4038	4260	4620	4640	4699
Texaco No. 1 R.E. Bair	NW-SE-28-34N-9E	3065	—	4440	—	4510	4700	4993	5015	5073
Seaboard No. 1 Dolezal	NE-SW-SW-21-35N-10E	2931	—	4490	4520	4569	4732	5122	5134	5189
Pure No. 1 August Tesarek	NW-NE-26-19N-13E	3628	—	4127	—	4164	4310	—	—	—
Texas No. 1 A. L. Kiemele	SE-NW-NE-26-31N-13E	2743	4470	4495	4515	4535	4745	—	—	5120
Texas Verploegen No. 1	C-NE-NE-31-36N-14E	3045	—	5109	5165	5190	5385	5730	5745	5805
Cities Service No. 1 Huffine	C-SW-SE-27-17N-15E	3949	—	5506	—	5547	5603	—	—	—
General Pete. No. 6-12P Erickson	SW-NE-11-36N-15E	2869	—	5108	5172	5196	5403	5740	5762	5828
Texas No. 1 Davis Ranch	C-SE-SW-4-29N-18E	3923	—	4120	4175	4200	4363	4662	4672	4752
Texas No. 1 G.A. Miller	NW-SE-SE-9-37N-18E	2845	—	5235	5327	5343	5542	5914	5933	6005
Northern Ordnance No. 5 Guertzgen	NE-SW-NW-1-31N-19E	2926	—	4275	4365	4390	4571	4812	4830	4900
Montana-Canadian No. 1 Sprinkle Land Co.	S½-SW-SW-28-31N-19E	3094	—	4560	4635	4665	—	—	—	—
Heyting No. 1 Blaine County	34-33N-19E	2437	—	4710	4785	4803	4992	5322	5332	5408
Empire State No. 1 Ford	C-SE-NE-3-22N-20E	3210	—	5471	—	5500	—	—	—	—
Mule Creek No. 1 Gov't	C-NE-SW-23-26N-20E	3464	—	5310	—	5360	5550	—	—	5800
Phillips Fort Belknap "A" No. 1	SW-NW-3-28N-23E	2916	—	4593	—	4680	4869	—	—	5237

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Amerada & Gulf Chris Molvig	E½-SW-NE-13-29N-37E	2238	—	5158	—	5238	5417	—	—	5755
Gulf No. 1 R. L. Cornwell	C-SW-NE-14-30N-38E	2344	—	5340	—	5428	5622	5894	5903	5965
Seaboard Rickter No. 1 Unit	C-SW-NE-18-32N-38E	2785	—	5550	—	5640	5820	6116	6122	6182
J.W. Brown No. 1 Binion	21-20N-39E	2800 (approx)	—	7148	—	7197	7329	—	—	7566
Plymouth No.1-20 Gov't	C-SE-NE-20-26N-39E	2195	—	5892	—	5972	6047	6304	6313	6364
Bert Fields No. 1 Steve Figmain	C-SW-NE-14-27N-39E	2357	—	5903	—	5993	6180	6429	6436	6490
Seaboard Tampico Unit No. 1	C-SE-NW-5-30N-39E	2512	—	5588	—	5670	5868	6130	6140	6209
Murphy No. 1 Firemoon	C-SE-SE-12-30N-41E	2733	—	6445	6499	6525	6698	6983	6988	7050
Gulf *et al* No. 1 Lentzner	C-NE-NE-9-32N-42E	2953	—	6679	—	6758	6915	7208	7217	7276
NP "F" No. 1	29-18N-43E	2613	—	8472 (E)	—	8510	8630	—	—	8863
Superior No. 22-10 Goff	C-SE-NW-10-19N-44E	2715	—	8450	8485	8506	8623	—	—	8900
Amerada No. 1 Rock Creek Unit	SW-SE-SW-10-22N-44E	2779	—	7562	—	7644	7792	8022	8027	8093
Zach Brooks #1 State	C-SE-SE-18-36N-44E	2994	--	7078	7130	7155	7323	7650	7655	7720
Gen. Pet. No. 88-30-5 Holt	SE-SE-SE-30-25N-1W	3544	—	2954	3000	3013	3162	3550	3562	3623
Montalban No. 1 McCracken	C-SW-SE-18-29N-1W	3381	—	3259	3290	3300	3449	3900	3910	3980

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Amerada No. 1 Burke	NW-SE-NE-25-17N-24E	3256	—	5995	6061	6083	—	—	—	—
Amerada No. 1 Lester Fastol	C-NW-SE-17-18N-24E	3267	—	—	—	5900 (E)	—	—	—	—
Phillips No. 1-A Savoya	C-NW-SW-26-31N-24E	2465	—	4669	4743	4764	—	—	—	—
Fair and Woodward No. 1 Miller	C-NE-SE-3-32N-24E	2725	—	5100	5205	5225	5424	—	—	—
Zach Brooks No. 1 Cowell	C-NE-NE-17-20N-25E	2936	—	5664	5702	5712	5900	—	—	—
Phillips Unit No. 1	SE-SE-NW-29-23N-26E	3070	—	5473	—	5520	5690	—	—	5959
Dekalb-North Oil Div. No. 1	C-NW-NW-19-23N-31E	2563	—	5440	5497	5518	5679	—	—	5947
Texas No. 1 Gov't	C-SE-SE-11-34N-31E	2305	—	4265	4349	4390	4575	4881	4888	4970
Texas No. 1 - 822 Bowdoin Unit	C-SW-SW-8-32N-32E	(approx.) 2280	00	4073	4166	4188	4389	4670	4676	4760
Shell No. 13-26 Gov't	C-NW-SW-26-31N-33E	2543	—	4531	4609	4629	4852	5100	5107	5184
California No. 1 Gov't	C-NE-NW-33-26N-34E	2551	—	5420	5484	5502	5693	—	—	5995
Texas Bowdoin 2-34-24 Unit	C-NW-NE-34-32N-34E	2259	—	4056	4147	4172	4349	4632	4638	4722
Gulf No. 1 Gov't	SW-SW-SW-31-37N-34E	2384	—	4840	4940	4982	5155	5504	5510	5580
Harrison & Abercrombie No 1-X Gov't Unit	C-NW-NW-19-25N-35E	2855	—	5896	5963	5984	6154	—	—	6458
Seaboard-Honolulu No. 1 Loberg	C-SE-NE-20-30N-36E	2480	—	5107	—	5192	5382	—	—	5715
Hunt & Gulf No. 1 J.J. Loberg	C-SW-SE-26-30N-36E	2496	—	5115	—	5210	5400	—	—	5727

Well Name	Location	Kelly Bushing Elevation (feet above sea level)	Torquay Formation	Birdbear Formation		Duperow Formation				
			Top of Unit 2 (feet below K.B.)	Top of Upper Member (feet below K.B.)	Top of Lower Member (feet below K.B.)	Top of Seward Member (feet below K.B.)	Top of Wymark Member (feet below K.B.)	Top of Elstow Member (feet below K.B.)	Top of Saskatoon Member (feet below K.B)	Top of Souris River Formation (feet below K.B.)
Farmers Union No./State 6444-61	C-NE-SE-36N-30N-1W	3586	—	3476	3509	3521	3659	4120	4130	4194
Renwar-Salvate No. 1 McKechnie	NE-SE-SE-131N-1W	3309	—	2950	2990	3003	3240	3597	3607	3672
Inland Empire No. 1 Lee Edwards	NE-NW-NE-17-35N-1W	3576	—	3000	3050	3070	3212	3700	3716	3770
Pan Am No. 1 Don Hadley	C-NW-SW-12-22N-2W	3821	--	3153	3180	3219	3320	3725	3735	3792
B.A. No. 1 Swenson	SE-NE-SE-7-24N-2W	3796	—	3100	3150	3160	3279	—	—	—
Montalban No. 1 Johnson	C-SE-NW-7-27N-2W	3714	—	3298	3340	3352	3497	3910	3920	3990
Pioneer No. 3 Shelton Gov't	C-SE-NW-4-34N-2W	3467	—	2812	2840	2857	2992	3495	3510	3728
Union No. 1 Emiley R. Jacobs	SW-SW-14-36N-2W	3378	—	3197	3244	3257	3367	—	—	N.P.
Union No. 1 Freda Brown	C-NE-NE-9-37N-2W	3488	—	3744	3805	3829	3947	N.P.	N.P.	N.P.
Montalban No. 1 M. Larsen	C-SW-NW-11-25N-3W	3708	—	3173	3220	3237	3397	—	—	3840
Anaconda No. 1 Bloom	SW-NE-29-20N-3W	3847	—	4473	4506	4527	4626	N.P.	N.P.	N.P.
Gen.Pet. Agewan #48-9-P	9-26N-4W	3975	—	3487	3520	3548	3772	—	—	4188
Empire No. 2 Border	11-37N-4W	3642	—	3991	4041	4051	4175	4632	4643	4740
Phillips No. 1 Randall	C-NE-SE-6-21N-5W	4462	—	5547	5580	5600	5762	—	—	6190
Union No. 418-7 Stuft	C-SW-NW-19-36N-5W	4010	—	4396	4430	4444	4622	5019	5035	5130
Phillips No. 1 Yeeger	C-SW-NW-6-23N-6W	4295	—	6067	6110	6130	6240	—	—	6692
Continental 14 No. 1 State	14-25N-6W	4329	—	4292	4333	4343	4471	—	—	4932

Well Name	Location	Kelly Bushing Elevation (feet above sea level)	Torquay Formation	Birdbear Formation		Duperow Formation				
			Top of Unit 2 (feet below K.B.)	Top of Upper Member (feet below K.B.)	Top of Lower Member (feet below K.B.)	Top of Seward Member (feet below K.B.)	Top of Wymark Member (feet below K.B.)	Top of Elstow Member (feet below K.B.)	Top of Saskatoon Member (feet below K.B)	Top of Souris River Formation (feet below K.B.)
No. 1 North Pendory	9-27N-6W	4231	—	4562	4627	4694	4825	N.P.	N.P.	N.P.
Union No. 1 Black foot Tribal 194-12	15-37N-7W	4130	—	5122	5148	5184	5389	—	—	5900

APPENDIX B

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GEOCHEMICAL ANALYSES

GEOCHEMICAL ANALYSES

Analytical Method

The partially cored or totally cored intervals of 31 anhydrite beds ranging in thickness from a minimum of one foot to a maximum of 36 feet, were sampled for this study. All anhydrite beds over 3 feet thick were sampled at one foot intervals beginning at the top of the interval or, where possible, at the upper contact of the anhydrite. The thinner beds were sampled at half foot intervals beginning at the upper contact where possible. In each case a 1 inch to 3 inch long sample was collected and from it a quarter of an inch thick lengthwise slab was removed. Each slab was then subjected to a primary crushing, by hand, using an iron pestle and mortar and the fragments were placed in a Pica Blender and crushed to an extremely fine powder (approximately - 325 mesh).

Each powder specimen was prepared for x-ray analysis by pressing it into a briquette having a cellulose rim and backing. The briquettes were formed by subjecting the powdered samples and cellulose to a pressure of 30,000 pounds per square inch using an hydraulic press. Considerable care had to be taken in applying and removing the pressure, as excessively rapid loading and unloading resulted in elastic rebound in the sample and consequent flaking of the anhydrite powder. Therefore, the specimens were loaded and unloaded at the rate of 10,000 pounds per square inch per 10 second interval.

Each anhydrite sample was analyzed for CaO, K_2O, MgO and Sr content using a Phillips Norelco Model 12215/0 x-ray fluorescence unit, operated under the conditions recorded in Table 3. This table also

SAMPLE IDENT.	1ST PEAK READING	2ND PEAK READING	BACKGROUND READING	AVG. PEAK LESS BKGRND	BACKGROUND DEVIATION	SQUARE OF DEVIATION	WEIGHT PERCENT	WT. PERC. DEVIATION	SQUARE OF DEVIATION	DATA SET
R-058	33370.5	33419.8	263.6	33131.5	-108.2	11708.4	49.0194	.1605	.0257	1
R-059	26853.8	26818.3	213.9	26622.1	-58.5	3422.9	39.3884			
D-051	17342.2	17240.7	132.4	17159.0	22.9	528.7	25.3874			
D-052	17847.8	17862.6	129.9	17725.3	25.4	649.9	26.2252			
R-058	33409.4	33277.7	267.8	33075.7	-112.4	12635.0	48.9368	.2431	.0591	2
D-055	17877.6	17837.8	133.0	17724.7	22.3	501.5	26.2243			
D-054	17509.5	17529.4	132.6	17386.8	22.7	519.5	25.7245			
D-050	21853.4	21970.8	164.6	21747.5	-9.2	84.7	32.1762			
R-058	33632.8	33530.8	258.8	33323.0	-103.4	10692.7	49.3026	-.1227	.0150	3
D-056	17831.9	17140.5	130.5	17355.7	24.8	619.7	25.6784			
D-057	16456.9	16643.1	138.6	16411.4	16.7	282.0	24.2812			
D-076	16788.4	16800.3	132.8	16661.5	22.5	510.5	24.6514			
R-058	32398.8	32276.0	249.4	32088.0	-94.0	8837.0	47.4754	1.7045	2.9053	4
D-A-1	16307.7	16383.7	121.2	16224.5	34.1	1169.2	24.0047			
D-001	16806.9	16569.3	123.4	16564.7	31.9	1023.6	24.5081			
D-002	16383.0	16209.7	123.5	16172.8	31.8	1017.2	23.9283			
R-058	32733.8	32549.8	247.2	32394.6	-91.8	8428.2	47.9290	1.2508	1.5647	5
D-003	16439.0	16316.8	118.6	16259.3	36.7	1353.8	24.0562			
D-004	16568.0	16454.2	123.8	16387.3	31.5	998.1	24.2456			
D-005	16732.8	16791.6	129.0	16633.2	26.3	696.6	24.6094			
R-058	31928.8	31696.2	276.8	31535.7	-121.4	14739.3	46.6582	2.5216	6.3588	6
D-006	15750.2	15888.2	127.8	15691.4	27.5	761.4	23.2160			
D-007	16427.8	16470.0	134.4	16314.5	20.9	440.7	24.1379			
D-008	17926.4	17320.8	147.2	17476.4	8.1	67.1	25.8570			
R-058	32743.7	32430.1	258.8	32328.1	-103.4	10692.7	47.8306	1.3492	1.8205	7
D-009	16662.1	16581.3	127.6	16494.1	27.7	772.5	24.4036			
D-011	16685.1	16523.8	123.7	16480.7	31.6	1004.5	24.3839			
D-012	16420.1	15832.2	135.6	15990.5	19.7	391.8	23.6586			
R-058	32857.4	32259.8	263.2	32295.4	-107.8	11622.0	47.7822	1.3976	1.9534	8
D-013	16244.6	16111.7	127.0	16051.1	28.3	806.2	23.7482			
D-014	16154.9	16053.1	127.0	15977.0	28.3	806.2	23.6385			
D-016	15714.7	15806.0	129.9	15630.4	25.4	649.9	23.1258			
R-058	32413.0	31462.6	291.0	31646.8	-135.6	18388.9	46.8226	2.3572	5.5568	9
D-017	15683.1	15740.7	142.4	15569.5	12.9	168.8	23.0356			
D-018	15940.0	16183.5	141.0	15920.7	14.3	207.1	23.5553			
D-019	16052.8	15812.4	136.8	15795.8	18.5	345.7	23.3704			
R-058	33317.5	33024.2	272.9	32897.9	-117.5	13807.5	48.6737	.5061	.2562	10
D-020	16529.0	16428.9	133.3	16345.6	22.0	488.1	24.1840			
D-021	16445.9	16594.9	126.4	16394.0	28.9	840.6	24.2555			
D-022	16362.8	16314.4	128.5	16210.1	26.8	723.3	23.9834			

Figure 26

includes the precision obtained on replicate x-ray analyses of the standard samples employed and the calculated detectability of each constituent. The detectability was taken as three standard deviations above mean background as suggested by Campbell and Williams (1965). Due to the make-up of the sample holder in the x-ray unit employed samples were analyzed in sets of three and a standard sample, as shown in Figure 28. A run of each sample consisted of two readings on the 2θ peak separated by a background reading, as is also illustrated in Figure 28.

Table 5

Constituent	Tube and Conditions[1]	External Standard	Detectability
CaO	Mo, 50kv, 40ma, EDDT, F.P.	49.17 $\pm$ .18%	.47%
K_2O	Mo, 50kv, 40ma, EDDT, F.P.	.57 $\pm$ .17%	.013%
Sr	Mo, 50kv, 40ma, LiF, Scint.	1345 $\pm$ 120 ppm	258 ppm
MgO	Mo, 50kv, 40ma, ADP, F.P.	2.5 $\pm$ 3.58%	20.2%
		14.85 $\pm$ 3.34%	
		21.69 $\pm$ 3.78%	

Preparation of External Standards

The external standards employed in the detection of CaO and K_2O concentrations were Mississippian carbonate samples R-58 and R-59 collected by J. Walasko (1962) and chemically analyzed in the Rock Analysis Laboratory of the Department of Geology, University of Alberta.

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[1] Information presented in this order: Tube, tube voltage and amperage, analyzing crystal, counter (flow proportional, or scintillation).

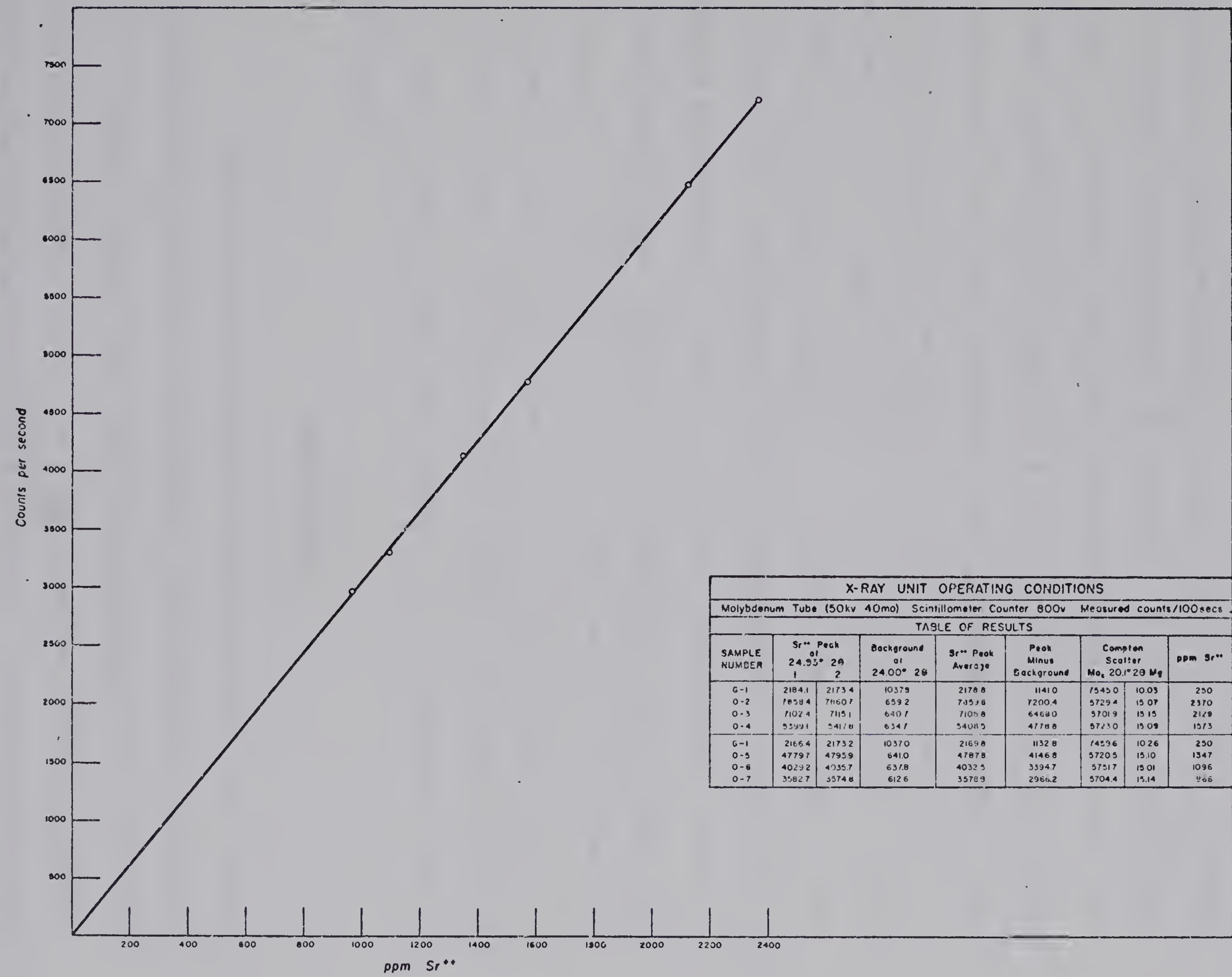
The chemical composition of these external standards is listed in Table 4. The above-mentioned standards and a 100% dolomite sample were used as external standards in the detection of the MgO concentration.

For the detection of strontium in the anhydrites a set of standard samples was prepared to establish a calibration curve for strontium. The standards were made up using a 20 gram sample of anhydrite from the "A" Evaporite of the Upper Ordovician Red River Formation. This sample was used because it was known to have 620 ppm strontium.

Table 4

Chemical Analyses of Mississippian Carbonates

	R-58	R-59
SiO_2	4.39%	2.04%
TiO_2	0.07%	0.06%
Al_2O_3	1.07%	0.62%
Fe_2O_3	0.62%	0.62%
FeO	nil	nil
MnO	0.02%	0.02%
MgO	2.51%	14.86%
CaO	49.18%	36.49%
Na_2O	0.05%	0.05%
K_2O	0.58%	0.28%
P_2O_5	0.10%	0.01%
H_2O-	0.09%	0.08%
H_2O+	0.35%	0.54%
CO_2	40.87%	44.54%
Total	99.82%	100.22%



X-RAY UNIT OPERATING CONDITIONS

Molybdenum Tube (50kv 40ma) Scintillometer Counter 800v Measured counts/100secs

TABLE OF RESULTS

SAMPLE NUMBER	Sr++ Peak at 24.93° 2θ 1	2	Background at 24.00° 2θ	Sr++ Peak Average	Peak Minus Background	Compton Scatter Mo_K 20.1° 2θ	Mg	ppm Sr++
G-1	2184.1	2173.4	1037.9	2178.8	1141.0	7545.0	10.03	250
O-2	7858.4	7860.7	659.2	7859.8	7200.4	5729.4	15.07	2370
O-3	7102.4	7115.1	640.7	7105.8	6468.0	5701.9	15.15	2129
O-4	5399.1	5417.8	634.7	5408.5	4778.8	5723.0	15.09	1573
G-1	2166.4	2173.2	1037.0	2169.8	1132.8	7459.6	10.26	250
O-5	4779.7	4795.9	641.0	4787.8	4146.8	5720.5	15.10	1347
O-6	4029.2	4035.7	637.8	4032.5	3394.7	5751.7	15.01	1096
O-7	3582.7	3574.8	612.6	3578.9	2966.2	5704.4	15.14	966

Figure 27

Loss on ignition	41.69%	25.15%

Parts of the 20 gram sample of anhydrite were mixed with varying proportions of strontium nitrate to produce standard samples containing the different concentrations of strontium. A strontium calibration curve was determined using the international standard G-1 as an external standard and by employing a matrix correction based on Compton scattering as outlined by Reynolds (1963). Strontium standard sample 0-5 was then chosen as the external standard for the detection of strontium in the anhydrite samples of the Duperow Formation. Because of the large number of samples to be analyzed, three samples, D-304, D-39 and D-270, representing varying concentrations of impurities, were chosen to determine the effect of matrix on the accuracy of the strontium determinations. However, it was found that only a slight difference existed between values obtained using a matrix correction based on Compton scattering and values obtained without giving consideration to matrix effect, and in the writer's opinion the accuracy obtained by the latter method was more than adequate for the purposes of the present study.

Calculations

All calculations required to synthesize the x-ray results were made using an I.B.M. 1410 computer. The program was written by Mr. K. Pullen, former I.B.M. liaison man attached to the Saskatchewan Government Computer Center. The program written in floating-point Fortran was stored with the Computer Center. A sample of the print-out is illustrated in Figure 28. The various steps employed to determine

the weight percent of CaO, K_2O, MgO and SrO in each sample, consisted of:

1) Determining the detectability - by calculating the standard deviation of the mean value of the background for a particular constituent, and then only accepting as detectable those values which were three standard deviations above mean background;

2) Establishing the conversion factor for a particular constituent - it was found that the calibration curves for each constituent approximated a straight line, and therefore, the conversion factor in each case was the slope of the calibration curve; and

3) Determining the weight percent of each constituent in the unknown samples - by multiplying the 2θ peak value for each constituent in each sample by the conversion factor.

The author also carried out an analysis of variance of the strontium-calcium ratios (q values of Muller, 1964) between the varieties of anhydrite as outlined in a previous section (Petrology of the Anhydrites, p. 116). Sample calculations of these analyses of variance are presented in Appendix C.

Results

The results of the x-ray analyses are recorded in Table 5 of this appendix, with the exception of the MgO values. Since this constituent was found to be detectable in only two samples, D-194, and D-223, both containing 20.8% MgO, a special column was felt to be unnecessary. Both of these samples are composed of dolomitic material with little or no anhydrite present and in both cases strontium is undetectable. A thin-section examination of many of the other samples leaves

little doubt that MgO is present in several of them, in dolomite, but under the analytical conditions used in this study the concentrations of MgO were too small to be detectable. The reason for the poor analytical results in the case of MgO may be interpreted from Table 5, where it can be seen that the precision on replicate runs on the external standard is poor to fair. External standard R-58 with a concentration of 2.5% MgO had the lowest precision with a variation of $\pm$ 3.58%. As the concentration of MgO increased the precision also improved as shown by R-59 and x-100. In the writer's opinion, the improvement in precision with increased MgO concentration indicates that the readings have been affected by the matrix. Matrix effect probably also caused a high background reading, thus requiring the presence of a high concentration of MgO before it would be detectable.

Although only two statistically significant MgO readings were obtained, some of the higher average peak-minus-background readings (especially those readings that were one and two standard deviations above mean background) were correlated with the strontium values for the same sample, and it was found that strontium concentration decreased with increased MgO concentration.

A comparison of K_2O and CaO values for the same samples showed that for the most part there is little correlation between the two values. In some instance an increase in K_2O correlates with a decrease in CaO content, but in other circumstances the opposite is true.

There appears to be a relationship between the strontium content of anhydrite and the calcium concentration. Commonly, an increase in the amount of calcium is accompanied by a decrease in

strontium. However, occasionally, the concentration of both constituents decreases and this is usually associated with an increase in potassium concentration. Three of the specimens analyzed, D-96, D-98, and D-104, contained above normal strontium values 27,975 ppm, 5,701 ppm and 4,696 ppm respectively. Thin sections of these specimens showed that celestite was present in the rocks. In each case the specimens consisted of fossiliferous and pelletoid carbonate associated with felty, bacillar and tabular anhydrite. The excess strontium required to produce the celestite probably had its source in the shell and pellet material in the rock. This material was probably originally composed of aragonite and had a high strontium content. When the aragonite was altered later to calcite the strontium that could not be retained in the calcite lattice was released and united with available sulphate ions to produce celestite. The source of the sulphate ions may have been the associated anhydrite.

The results of the strontium analyses accompanied by the K_2O concentrations and the Sr/CaO x 1000 ratios (henceforth called t values, which can be converted to Sr/Ca x 1000 ratios, q values of Muller-1964, by multiplying them by a correction factor of 1.4) were plotted on profiles (Figures 21 to 25, inclusive). Each profile was plotted in anticipation that the patterns of strontium distribution, or a combination of the former and the K_2O and t values distributions, might produce some characteristic that could be used to identify stratigraphically equivalent anhydrites. In order to determine whether the variation in strontium content was dependent on the character of the anhydrite, a representative sampling of the strontium content and t values were grouped according to the category of anhydrite from which the analyzed specimen

was taken (Table 6). Analyses of variance of the t values for the various categories of anhydrites were performed and the results are presented in Appendix C.

The mean strontium concentrations and mean q values for each type of anhydrite were determined and are listed below accompanied by the range within which 99.7% (3 standard deviations) of the samples for a particular category may be found:

1) Bedded Anhydrite	1397 $\pm$ 516 ppm Sr
	$q = 8.0 \pm 3.0$
2) Nodular Anhydrite	1606 $\pm$ 336 ppm Sr
	$q = 9.1 \pm 2.5$
3) Mottled Anhydrite	1256 $\pm$ 441 ppm Sr
	$q = 6.9 \pm 2.8$
4) Interlaminated Anhydrite and Dolomite	1190 $\pm$ 573 ppm Sr
	$q = 6.9 \pm 3.1$
5) Replacement Anhydrite	1135 $\pm$ 840 ppm Sr
	$q = 6.0 \pm 5.7$

The q values for bedded and nodular anhydrite are considerably above the maximum limit (7) for isomorphous strontium in anhydrite as proposed by Muller (1964). However, since no celestite was detected in any thin sections of bedded and nodular anhydrite, the writer is of the opinion that Muller's maximum q value limit is not applicable in this study and a more realistic maximum value for anhydrites of that formation may be in the order of 12.

TABLE 5

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Results of X-ray Analyses

Specimen Number	Well Name	Depth	Land Location	CHEMICAL ANALYSES			†
				K20 Weight %	CaO Weight %	Sr ppm	$\left(\frac{Sr}{CaO} \times 1000\right)$
D-A-1	Tidewater Morse Cr. #1	5025.3	16-25-16- 8W3	.0873	24.0047	1312	5.5
D-1		5026			24.5081	1482	6.0
D-2		5027		.0466	23.9283	1462	6.1
D-3		5028			24.0562	1613	6.7
D-4		5029			24.2456	1653	6.8
D-5		5030			24.6094	1509	6.1
D-6		5031			23.2160	1548	6.6
D-7		5032			24.1379	1488	6.2
D-8		5033			25.8570	1084	4.2
D-9		5034		.0302	24.4036	1612	6.6
D-10		5035			24.9861	1611	6.5
D-11		5036		.0135	24.3839	1669	6.8
D-12		5037			23.6586	1885	7.9
D-13		5038			23.7482	1783	7.5
D-14		5039			23.6385	1690	7.2
D-15		5040			25.0284	1729	6.9
D-16		5041			23.1258	1706	7.4
D-17		5042			23.0356	1816	7.9
D-18		5043			23.5553	1614	6.9
D-19		5044			23.3704	1593	6.8

Specimen Number	Well Name	Depth	Land Location	CHEMICAL ANALYSES			†
				K_2O Weight %	CaO Weight %	Sr ppm	$(\frac{Sr}{CaO} \times 1000)$
D-20	Tidewater Johnstone Lake Cr. #1	5489	9-20-12- 2W3		24.1804	1592	6.6
D-21		5490			24.2555	1591	6.6
D-22		5491			23.9834	1268	5.3
D-23		5492			25.7568	1410	5.5
D-24		5493			25.3939	1549	6.1
D-25		5494			24.6140	1579	6.4
D-26		5495			24.7914	1648	6.7
D-27		5496			25.1986	1655	6.6
D-28		5497			25.4945	1631	6.4
D-29		5498			24.9225	1697	6.8
D-30		5499			24.8376	1576	6.4
D-31		5500			24.7942	1664	6.7
D-32		5501			25.3153	1743	6.9
D-33		5502			25.3891	1652	6.5
D-34		5503			25.5184	1451	5.7
D-35		5504			25.8522	1680	6.5
D-36	Tidewater Parkbeg Cr. #1	4814	10-32-18- 3W3		26.5686	1376	5.2
D-37		4815			24.1626	1314	5.4
D-38		4816		.0283	24.5982	1446	5.9
D-39		4817			24.7040	1392	5.6

Specimen Number	Well Name	Depth	Land Location	CHEMICAL ANALYSES K20 Weight %	CaO Weight %	Sr ppm	† $(\frac{Sr}{CaO} \times 1000)$
D-40	Tidewater Parkbeg Cr. #1	4818	10-32-18- 3W3		25.7781	1395	5.4
D-41		4819			25.4433	1375	5.4
D-42		4820			24.9229	1468	5.9
D-43		4821		.0148	25.5568	1464	5.7
D-44		4822			24.8198	1410	5.7
D-45		4823		.-138	24.8179	1478	6.0
D-46		4824			25.1091	1409	5.6
D-47		4825			25.6143	1399	5.5
D-48	Sohio Standard Regent Wood Mountain #1	7062.5	9-18- 3- 3W3		23.7180	1216	5.1
D-49		7063			24.8146	1284	5.2
D-50		7064		.0249	32.1762	1030	3.2
D-51		7065			25.3874	1288	5.1
D-52		7066			26.2252	1210	4.6
D-53		7067			25.1925	1334	5.3
D-54		7068			25.7245	1202	4.7
D-55		7069		.0163	26.2243	1247	4.7
D-56		7070			25.6784	1228	4.8
D-57		7071			24.2812	1343	5.5
D-58	Imperial Dinsmore #1-32-27-11	3805	1-32-27-11W3	.0154	26.4717	1426	5.4
D-59		3806		.0213	26.0944	1562	6.0

Specimen Number	Well Name	Depth	Land Location	CHEMICAL ANALYSES			†
				K20 Weight %	CaO Weight %	Sr ppm	$(\frac{Sr}{CaO} \times 1000)$
D-60	Imperial Dinsmore #1-32-27-11	3807	1-32-27-11W3	.0163	27.9841	1393	5.0
D-61		3808		.0443	26.1441	1315	5.0
D-62		3809		.0552	24.2441	1265	5.2
D-63		3810		.0491	24.2737	1383	5.7
D-64		3811			25.0164	1424	5.7
D-65		3812			25.1191	1458	5.8
D-66		3813			25.3024	1375	5.5
D-67		3814			24.7674	1342	5.4
D-68		3815			26.0978	1320	5.1
D-69		3816			24.9359	1345	5.4
D-70		3817			25.4248	1400	5.5
D-71		3818			25.1641	1485	5.9
D-72		3819			25.2591	1392	5.5
D-73		3820		.1306	26.4350	1015	4.0
D-74		3821			25.0738	1336	5.3
D-75		3822			24.8655	1521	6.1
D-76		3823			24.6514	1363	5.5
D-77		3824			25.3733	1502	5.9
D-78		3825			25.0181	1574	6.3
D-79		3826			25.4945	1457	5.7
D-80		3827			25.4741	1610	6.3

Specimen Number	Well Name	Depth	Land Location	CHEMICAL ANALYSES K20 Weight %	CaO Weight %	Sr ppm	† $(\frac{Sr}{CaO} \times 1000)$
D-81	Imperial Dinsmore #1-32-27-11	3828	1-32-27-11W3		24.8421	1625	6.6
D-82		3829			25.2538	1689	6.7
D-83		3830			25.2162	1660	6.6
D-84		3831			25.5911	1556	6.1
D-85		3832		.0173	26.1314	1510	5.8
D-86		3833			24.5924	1615	6.6
D-87		3834			25.7457	1441	5.6
D-88		3835			25.6560	1357	5.3
D-89		3835.4		.2374	45.6261	0614	1.3
D-90		3843.2			28.8672	1047	3.6
D-91		3844.2			26.7466	1409	5.3
D-92		3845.2			30.3870	0522	1.7
D-93		3846.2			26.1859	1327	5.1
D-94		3847.2			24.6088	1626	6.6
D-95		3848.2			24.3466	1335	5.5
D-96		3849.2			25.2909	27975	110.8
D-97		3855			28.8885	0864	3.0
D-98		3856			29.5083	5701	19.3
D-99		3857			30.3993	1111	3.7
D-100		3858			24.6408	1542	6.3
D-101		3859			27.6138	1268	4.6

Specimen Number	Well Name	Depth	Land Location	CHEMICAL ANALYSES			†
				K20 Weight %	CaO Weight %	Sr ppm	$(\frac{Sr}{CaO} \times 1000)$
D-102	Imperial Dinsmore #1-32-27-11	3860	1-32-27-11W3		25.2289	1317	5.2
D-103		3861			29.0368	1160	4.0
D-104		3862			26.5871	4696	17.7
D-105		3863			26.9685	1435	5.3
D-106		3864			25.1188	1408	5.6
D-107		3865			24.2854	1338	5.5
D-108		3866			26.1098	1349	5.2
D-109		3867			26.1157	1326	5.1
D-110		3868			25.9558	1331	5.1
D-111		3869			25.4954	1335	5.3
D-112		3870			25.4289	1467	5.8
D-113		3871			25.7806	1325	5.1
D-114		3872			24.9809	1360	5.5
D-115		3873			25.3055	1403	5.5
D-116		3874		.0158	25.2464	1649	6.5
D-117		3875			28.1229	1603	5.7
D-118		3876		.0168	31.0136	1125	3.6
D-119		3877			25.3268	1351	5.3
D-120		3878			25.3249	1316	5.2
D-121		3879			25.4967	1383	5.4
D-122		3880		.0335	26.6538	1371	5.2

Specimen Number	Well Name	Depth	Land Location	CHEMICAL ANALYSES K20 Weight %	CaO Weight %	Sr ppm	† ($\frac{Sr}{CaO}$ x 1000)
D-143	Tidewater Wymark Cr. #1	5431	3-10-14-14W3		26.2573	1396	5.3
D-144		5432			25.5532	1323	5.2
D-145		5441		.0309	25.0883	1424	5.7
D-146		5442			24.7547	1399	5.7
D-147		5443		.0163	25.3030	1667	6.6
D-148		5444			24.8566	1507	6.1
D-149		5445			24.7614	1564	6.3
D-150		5446			24.6960	1496	6.1
D-151	Imperial Lawson #1	4375.5	16-31-21- 6W3	.0193	24.4946	1217	5.0
D-152		4376.5			25.2234	1302	5.2
D-153		4377.5			24.4925	1098	4.5
D-154		4378		.0662	28.3199	0704	2.5
D-155	Tidewater Vanguard Cr. #1	5575.5	14-30-12- 9W3	.4754	25.3523	0655	2.6
D-156		5576		.0154	25.0036	1713	6.9
D-157		5576.7		.0422	24.4626	1322	5.4
D-158		5577.5			26.9508	1508	5.6
D-159	Tidewater Beechy Cr. #1	4096	1-29-23-11W3		25.0086	1481	5.9
D-160		4097		.0144	25.1709	1488	5.9
D-161		4098		.0154	25.7602	1647	6.4
D-162		4099			24.9361	1563	6.3
D-163		4100			25.0552	1583	6.3

Specimen Number	Well Name	Depth	Land Location	CHEMICAL ANALYSES			†
				K2O Weight %	CaO Weight %	Sr ppm	$(\frac{Sr}{CaO} \times 1000)$
D-123	Imperial Dinsmore #1-32-27-11	3881	1-32-27-11W3	.0146	37.4441	1044	2.8
D-124		3881.5			31.0308	0572	1.9
D-125		3902.7		.2583	24.6714	1496	6.1
D-126		3903.7		.1485	24.7504	1437	5.8
D-127		3904.7		.1358	24.5334	1416	5.8
D-128		3905.7		.1942	23.8401	1315	5.5
D-129		3907.8		.5503	21.4472	1085	5.1
D-130		3908.8			26.1296	1271	4.9
D-131		3909.8			25.3955	1293	5.1
D-132		3910.8		.0246	26.2789	1164	4.4
D-133		3911.8			25.3589	1249	4.9
D-134		3912.8			25.1292	1226	4.9
D-135		3913.8			25.5115	1217	4.8
D-136	Tidewater Wymark Cr. #1	5424	3-10-14-14W3	.0746	26.3363	1224	4.7
D-137		5425			24.6562	1518	6.2
D-138		5426			24.6745	1676	6.8
D-139		5427			24.6319	1530	6.2
D-140		5428			25.3045	1594	6.3
D-141		5429			25.0154	1626	6.5
D-142		5430			24.2212	1565	6.5

Specimen Number	Well Name	Depth	Land Location	CHEMICAL ANALYSES			†
				K20 Weight %	CaO Weight %	Sr ppm	$(\frac{Sr}{CaO} \times 1000)$
D-164	Tidewater Beechy Cr. #1	4101	1-29-23-11W3		25.7436	1579	6.1
D-165		4128.7		.3519	23.6576	1110	4.7
D-166		4129.7		.4199	22.5583	1374	6.1
D-167		4130.7			25.5143	1477	5.8
D-168		4131.8		.0205	26.7780	2158	4.7
D-169		4132.8		.0419	28.7073	0990	3.5
D-170		4133.9		.2668	24.5104	1200	4.9
D-171		4134.9		.3886	22.8939	1155	5.0
D-172		4136		.5625	21.6962	1093	5.0
D-173		4137		.3869	22.7647	1212	5.3
D-174		4138		.0223	25.2711	1509	6.0
D-175		4144.7		.4243	24.1124	0945	3.9
D-176		4145.8		.0199	25.2536	1480	5.9
D-177		4146.8			25.4701	1503	5.9
D-178		4147.7			25.3030	1291	5.1
D-179		4148.1		.0199	28.4513	0997	3.5
D-180	Tidewater Duperow Cr. #1	3041.5	4- 9-35-16W3	.0647	24.7658	1272	5.1
D-181		3042		.0300	25.3742	1130	4.5
D-182		3042.5		.0359	25.2320	1030	4.1
D-183		3330			25.8953	1191	4.6
D-184		3331			25.9462	1165	4.5

Specimen Number	Well Name	Depth	Land Location	CHEMICAL ANALYSES			†
				K20 Weight %	CaO Weight %	Sr ppm	$(\frac{Sr}{CaO} \times 1000)$
D-185	Tidewater Duperow Cr. #1	3332	4- 9-35-16W3		25.9256	1067	4.1
D-186		3333			26.2353	1067	4.1
D-187		3334			24.9932	0993	4.0
D-188		3335			25.4069	1120	4.4
D-189		3336		.0284	24.7951	1136	4.6
D-190		3337			25.0296	1162	4.6
D-191		3338			25.2140	1149	7.6
D-192		3339		.0310	25.7825	1166	4.5
D-193		3340		.0150	25.8491	1099	4.3
D-194		3341		.1376	31.6952	N.D.	
D-195		3342		.0258	25.3218	1359	5.4
D-196		3343		.1021	29.8567	0603	2.0
D-197		3344		.0213	24.6315	1337	5.4
D-198		3345		.0335	24.9210	1184	4.8
D-199		3346		.0266	25.7574	1244	4.8
D-200	Tidewater Parkbeg Cr. #1	4756.7	10-32-18- 3W3	.8420	19.8585	0730	3.7
D-201		4757			25.1370	1283	5.1
D-202		4758			25.5825	1280	5.0
D-203		4759			25.4013	1347	5.3
D-204		4760.5			19.3310	1126	5.8
D-205		4761			24.3845	1283	5.3

Specimen Number	Well Name	Depth	Land Location	CHEMICAL ANALYSES			†
				K20 Weight %	CaO Weight %	Sr ppm	$(\frac{Sr}{CaO} \times 1000)$
D-206	Tidewater Parkbeg Cr. #1	4762	10-32-18- 3W3		25.4175	1313	5.2
D-207		4763			25.2431	1263	5.0
D-208		4764			25.5341	1255	4.9
D-209		4765			25.6815	1291	5.0
D-210		4766.1		.0312	25.0922	1146	4.6
D-211		4767.5		.0173	26.4454	1367	5.2
D-212		4768		.0616	26.7203	1149	4.3
D-213		4773.2		1.0505	18.6016	0894	4.8
D-214		4774.2			27.8264	1196	4.3
D-215		4775.2			24.6961	1401	5.7
D-216		4775.7		.0327	25.6649	1214	4.7
D-217	Tidewater Eastend Cr. #5-12	6098.3	5-12- 6-20W3		24.8885	1258	5.1
D-218		6099			24.8466	1293	5.2
D-219		6100			24.9180	1262	5.1
D-220		6101			25.9693	1319	5.1
D-221		6102			25.0348	1451	5.8
D-222		6102.6			28.5756	1302	4.6
D-223	Mobil Oil North Richmound No. 31-1	4733	1-31-18-28W3	.0528	32.0052		
D-224		4734			25.7472	1180	4.6
D-225		4735			25.4659	1283	4.6
D-226		4736			24.9553	1358	5.0

Specimen Number	Well Name	Depth	Land Location	CHEMICAL ANALYSES K20 Weight %	CaO Weight %	Sr ppm	† $(\frac{Sr}{CaO} \times 1000)$
D-227	Mobil Oil North Richmound No. 31-1	4737	1-31-18-28W3		24.6465	1333	5.5
D-228		4738			24.8745	1355	5.4
D-229		4739		.0519	26.7410	1177	5.5
D-230		4740			25.7784	1275	4.4
D-231		4741			25.2881	1265	4.9
D-232		4742			25.5710	1252	5.0
D-233		4743			25.0932	1237	4.9
D-234		4744			25.4832	1303	4.9
D-235		4745			24.9382	1312	5.1
D-236		4746			20.6657	1231	5.3
D-237		4747			24.6569	1303	6.0
D-238		4748			25.3708	1201	5.3
D-239		4749					
D-240		4750					
D-241		4751		.3770	25.2171	0639	2.5
D-242		4752			24.8975	1362	5.5
D-243		4753		.0632	24.6141	1312	5.3
D-244		4754		.0237	24.9423	1418	5.7
D-245		4755		.0146	25.2561	1349	5.5
D-246		4756		.0391	24.5340	1215	5.0

Specimen Number	Well Name	Depth	Land Location	CHEMICAL ANALYSES			†
				K_2O Weight %	CaO Weight %	Sr ppm	$(\frac{Sr}{CaO} \times 1000)$
D-247	Mobil Oil North Richmound No. 31-1	4757	1-31-18-28W3	.0179	25.7084	1351	5.3
D-248		4758			25.7347	1252	4.9
D-249		4758.4		.0355	26.5371	1139	4.3
D-250		4759		.3343	30.3781	0393	1.3
D-251		4760		.0185	24.9883	1291	5.2
D-252		4761		.0146	25.8504	1321	5.1
D-253		4762		.0620	31.8876	1004	3.2
D-254	Tidewater Eastend Cr. #1	6077	15-11- 6-20W3		25.1203	1388	5.5
D-255		6078			25.2591	1476	5.9
D-256		6079			25.2826	1409	5.6
D-257		6080			25.2045	1395	5.5
D-258		6172.3		.0148	25.3091	1587	6.3
D-259		6173		.0367	24.7606	1607	6.5
D-260		6174		.0578	24.4927	1562	6.4
D-261		6175		.0740	24.5140	1516	6.2
D-262		6176		.0456	24.3353	1641	6.7
D-263		6177		.0759	23.7917	1578	6.6
D-264		6178		.0800	24.1707	1570	6.5
D-265		6179		.0393	24.7038	1520	6.2
D-266		6180		.0971	23.8590	1339	5.6
D-267		6181		.0582	24.4471	1502	6.2

Specimen Number	Well Name	Depth	Land Location	CHEMICAL ANALYSES			'
				K20 Weight %	CaO Weight %	Sr ppm	($\frac{Sr}{CaO}$ x 1000)
D-268	Tidewater Eastend Cr. #1	6182	15-11- 6-20W3	.0786	25.1403	1247	4.9
D-269		6183			25.4107	1440	5.5
D-270		6184		.0233	17.5539	1194	6.8
D-271		6185		.0492	25.3297	1403	5.5
D-272		6186			26.0579	1321	5.1
D-273	Royalite General American Coleville Disposal Well #1	3568.6	15-31-31-23W3	.0382	27.1829	1476	5.4
D-274		3569.6		.0177	25.9756	1503	5.8
D-275		3570.6			25.1780	1316	5.2
D-276		3571.6			25.4874	1155	4.5
D-277		3572.6			25.1724	1313	5.2
D-278		3573.6			25.3329	1443	5.7
D-279		3574.6			25.0539	1452	5.8
D-280		3584		.5174	22.9463	0951	4.2
D-281		3585		.0233	26.6513	1308	4.9
D-282		3586		.0357	26.5716	1035	3.9
D-283		3587		.2405	25.5618	0949	3.7
D-284		3588		.0260	27.3319	0987	3.6
D-285		3589		.0341	27.7568	.0933	3.4
D-286		3683			30.5609	0549	1.8
D-287		3684			25.8905	1047	4.1
D-288		3685			27.5994	0825	3.0

Specimen Number	Well Name	Depth	Land Location	CHEMICAL ANALYSES			†
				K20 Weight %	CaO Weight %	Sr ppm	$(\frac{Sr}{CaO} \times 1000)$
D-289	Royalite General American Coleville Disposal Well #1	3686	15-31-31-23W3		24.7923	1072	7.3
D-290		3687			28.5213	0765	2.7
D-291		3688			27.1757	0973	3.6
D-292		3689			25.8720	1120	4.3
D-293		3690			25.9650	1095	4.2
D-294		3691			27.3363	0980	3.6
D-295		3692			27.2948	0934	3.4
D-296		3693		.0236	26.7950	1105	4.1
D-297		3694			25.8726	1026	4.0
D-298		3695			26.2993	1037	3.9
D-299		3696			30.1284	0714	2.4
D-300		3697			26.0602	1075	4.1
D-301		3698			36.2602	1114	3.1
D-302		3699			28.3080	0763	2.7
D-303		3700			29.8514	0760	2.6
D-304		3701		.0167	51.0568	0350	.6
D-305		3702			44.7150	0468	1.0
D-306		3703			24.7483	1133	4.6
D-307		3704			26.5526	1177	4.4
D-308		3705			25.5819	1128	4.4

Specimen Number	Well Name	Depth	Land Location	CHEMICAL ANALYSES K20 Weight %	CaO Weight %	Sr ppm	† $(\frac{Sr}{CaO} \times 1000)$
D-309	Royalite General American Coleville Disposal Well #1	3706	15-31-31-23W3		26.4065	1050	4.0
D-310		3707			27.3559	0851	3.1
D-311		3708			35.3189	0665	1.9
D-312		3709			27.3878	1020	3.7
D-313		3710			27.0517	1023	3.8
D-314		3711		.0139	38.4256	0635	1.7
D-315		3712			34.9888	0558	1.6
D-316		3713			27.7827	0942	3.4
D-317		3714			25.3813	1139	4.5
D-318		3715			26.8135	1450	5.4
D-319		3721			25.6270	1088	4.3
D-320		3722			31.0664	0779	2.5
D-321		3723			27.3426	0986	3.6
D-322		3724			29.2379	0861	2.9
D-323		3725			26.7278	0997	3.7
D-324		3726			25.7585	1070	4.2
D-325		3727			25.7049	1193	4.6
D-326		3728			26.5171	0984	3.7
D-327	Tidewater Swanson Cr. #1	2818.3	4- 8-32- 9W3	.0447	27.3023	1695	6.2
D-328		2819.2			24.8384	1372	5.5
D-329		2820.1		.1341	24.7864	1279	5.2

Specimen Number	Well Name	Depth	Land Location	CHEMICAL ANALYSES			†
				K20 Weight %	CaO Weight %	Sr ppm	$(\frac{Sr}{CaO} \times 1000)$
D-330	Tidewater Swanson Cr. #1	2821	4- 8-32- 9W3	.1113	24.6960	1318	5.3
D-331		2822		.8577	20.0671	1004	5.0
D-332		2823.3			25.0561	1170	4.7
D-333		2824.3		.0446	26.9586	1156	4.3
D-334		2825.4			25.6469	1217	4.7
D-335		2826.4		.0513	25.9472	1117	4.3
D-336		2827.4			25.6772	1196	4.7
D-337		2828.4			25.5319	1183	4.6
D-338		2828.7		.0540	25.8815	0579	2.2
D-339		2945.9		.0151	25.3205	1053	4.2
D-340		2946.9			24.8234	1122	4.5
D-341		2947.9			25.3430	1291	5.1
D-342		2948.9			25.3045	1191	4.7
D-343		2949.9			27.5340	1003	3.6
D-344		2950.9			24.4449	1255	5.1
D-345		2951.9		.0794	25.5346	1009	4.0
D-346		2952.9		.0577	27.7781	0933	3.4
D-347		2953.9			24.9990	1271	5.1
D-348	Tidewater Imperial Outlook #1	2837.7	7-20-30- 7W3	.0594	26.0292	0755	2.9
D-349		2838.7			24.5638	1087	4.4

Specimen Number	Well Name	Depth	Land Location	CHEMICAL ANALYSES			†
				K20 Weight %	CaO Weight %	Sr ppm	$\left(\frac{Sr}{CaO} \times 1000\right)$
D-350	Tidewater Imperial Outlook #1	2839.7	7-20-30- 7W3		25.7901	1113	4.3
D-351		2840.7			24.9716	1060	4.3
D-352		2841.7		.0181	25.2712	1192	4.7
D-353		2842.7			24.6872	1259	5.1
D-354		2843.7			27.0002	0786	2.9

APPENDIX C

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Analyses of Variances

ANALYSES OF VARIANCE OF t VALUES

The variation in the t values of the five categories of anhydrite (see Petrology and Geochemistry of the Anhydrites, p. 116) was analyzed according to methods presented in Moroney (1962, pp. 371-380). He presented two methods; one to be used when an unequal number of samples in each category are to be analyzed, and the other when there is an equal number of samples per category. Sample calculations using both methods are presented below.

Sample Calculation No. 1

This is an analysis of variance for two anhydrite categories having unequal numbers of t values per category. In this example bedded anhydrite and interlaminated anhydrite and dolomite are the two categories. The t values are presented in Table 8. Seven steps are required to complete the analysis.

1) Obtain the grand average of all t values in the two categories

$$\text{Grand Average} = \frac{\text{Grand Total of all t values}}{\text{Total Number of Readings (N)}}$$

$$= \frac{227.2 + 122.7}{65}$$

$$= 5.3$$

2) Determine total degrees of freedom

$$df = N-1$$

$$= 65-1$$

$$= 64$$

3) Obtain the grand total of the squares of the deviations from the grand average of t values.

$$= (\text{Grand Average - each t value for bedded anhydrite})^2$$

$$+ (\text{Grand Average - each t value for interlaminated rocks})^2$$

$$= 25.53 + 16.49$$

$$= 42.02$$

4) Determine the between categories sum of squares (squares of the deviation from the grand average). To do this the effect of the within categories sums of squares must first be removed. This is accomplished by substituting the mean t values (5.7 and 4.9) of each category for each t value in the category.

Sum of between categories squares -

$$= (5.3 - 5.7)^2 \times 40 + (5.3 - 4.9)^2 \times 25$$

$$= 6.4 + 4.0$$

$$= 10.4$$

5) Determine the within category sum of squares. This is done by removing the effect of the between categories sum of squares. This is accomplished by determining the deviation of each t value in a category from the mean t value of each category.

Within category sum of squares -

$$= 18.90 + 12.72$$

$$= 31.62$$

6) Determine the degrees of freedom within category:

$$d.f. = N_1 - 1 + N_2 - 1$$

$$= 40-1 + 25-1$$

$$= 63$$

Between category d.f. = number of categories - 1

= 2 - 1

= 1

7) Table of Analysis of Variance

Source of Variation	Sums of Squares	Degrees of Freedom	Variance Estimate
Between Category	10.4	1	$\frac{10.4}{1} = 10.4$
Within Category	31.62	63	$\frac{31.62}{63} = .502$
Total	42.02	64	$F = \frac{10.4}{.502} = 20.7$

Therefore from a consultation of tables of F values for 5%, 1% and 0.1% levels of confidence it can be concluded that there is a statistically significant difference between the mean t values for bedded anhydrite and interlaminated anhydrite and dolomite.

Sample Calculation No. 2

This is an analysis of variance for two anhydrite categories having the same number of t values. In this example bedded anhydrite and nodular anhydrite are employed. The t values are present in Table 5. Six steps are required to complete this analysis.

1) Because this is a short method of calculating an analysis of variance it is necessary to first calculate a correction factor which will be employed in all other calculations. The correction factor consists of the

square of the grand total of all t values in the two categories divided by the number of t values.

$$\text{Correction Factor} = \frac{T^2}{N}$$

$$= \frac{(487.8)^2}{80}$$

$$= 2974.36$$

2) Determine the total sum of squares (grand total of squares of t values) - correction factor = (1711.54 + 1310.34) - 2974.36 = 47.52

3) Determine between category sum of squares

$$= \frac{\text{sum of the squares of the category totals}}{\text{number of items making up each category total}} - \text{correction factor}$$

$$= (260.6)^2 + (227.2)^2 - 2974.36$$

$$= 11.45$$

4) Determine within category sum of squares

= Total sum of squares - between category sum of squares

= 47.52 - 11.45

= 36.07

5) Determine degrees of freedom

Between category d.f. = 2 - 1

= 1

Within category d.f. =79 - 1

=78

6) Table of Analysis of Variance

Source of Variation	Sums of Squares	Degrees of Freedom	Variance Estimate
Between Category	11.45	1	$\frac{11.45}{1} = 11.45$
Within Category	36.07	78	$\frac{36.07}{78} = .46$
Total	47.52	79	$F = \frac{11.45}{.46} = 24.9$

Therefore from a consultation of tables of F values for 5%, 1% and 0.1% levels of confidence it can be concluded that there is a statistically significant difference between the mean t values for nodular anhydrite and bedded anhydrite.

Table of Analysis of Variance

(Nodular and Mottled Anhydrite)

Source of Variation	Sums of Squares	Degrees of Freedom	Variance Estimate
Between Category	58.83	1	$\frac{58.83}{1} = 58.83$
Within Category	29.40	78	$\frac{29.40}{78} = .376$
Total	88.23	79	$F = \frac{58.83}{.376} = 156.46$

Therefore from a consultation of tables of F values for 5%, 1% and 0.1% levels of confidence, it can be concluded that there is a statistically significant difference between the mean t values for mottled anhydrite and replacement anhydrite.

Table of Analysis of Variance

(Mottled and Replacement Anhydrite)

Source of Variation	Sums of Squares	Degrees of Freedom	Variance Estimate
Between Category	10.26	1	$\frac{10.26}{1} = 10.26$
Within Category	119.65	102	$\frac{119.65}{102} = 1.17$
Total	129.91	103	$F = \frac{10.26}{1.17} - 8.8$

Therefore from a consultation of tables of F values for 5%, 1% and 0.1% levels of confidence, it can be concluded that there is a statistically significant difference between the mean t values for mottled anhydrite and replacement anhydrite. However, the calculated F value is below the tabulated F value for the 0.1% level of confidence, meaning that the chances of the mean t values of mottled and replacement anhydrite being the same are greater than 1 in 100 but less than 1 in 1,000.

TABLE 6

Strontium & t Values Grouped According to Anhydrite Categories

Nodular		Bedded		Laminated		Mottled		Replacement	
t	Srppm	t	Srppm	t	Srppm	t	Srppm	t	Srppm
6.1	1462	4.0	1015	5.7	1424	5.3	1268	3.6	1047
6.7	1613	5.3	1336	5.7	1399	5.5	1410	5.3	1409
6.8	1653	6.1	1521	6.6	1667	6.1	1549	1.7	522
6.1	1509	5.5	1363	3.5	990	5.1	1216	5.1	1327
6.5	1611	5.2	1371	5.1	1272	5.2	1284	6.6	1626
6.8	1669	6.1	1496	4.5	1130	3.2	1030	5.5	1335
7.9	1885	5.8	1437	4.1	1030	5.1	1288	3.0	864
7.5	1783	5.8	1416	4.3	1099	4.6	1210	3.7	1111
7.2	1690	5.5	1315	5.4	1359	5.3	1334	6.3	1542
6.9	1729	5.1	1085	5.2	1367	4.7	1202	4.6	1268
7.4	1706	5.9	1481	4.9	1252	4.7	1247	5.2	1317
7.9	1816	5.9	1488	4.3	1139	4.8	1228	4.0	1160
6.9	1614	6.4	1647	5.2	1291	5.5	1343	5.3	1435
6.8	1593	6.3	1563	4.2	951	4.6	1191	5.6	1408
6.6	1592	6.3	1583	4.9	1308	4.5	1165	5.5	1338
6.6	1591	6.1	1579	3.9	1035	4.1	1067	5.2	1349
6.4	1579	4.7	1110	6.2	1695	4.1	1067	5.1	1326
6.7	1648	6.1	1374	5.5	1372	4.0	993	5.1	1331
6.6	1655	3.9	945	5.2	1279	5.1	1283	4.6	1180
6.4	1631	5.4	1337	5.3	1318	5.0	1280	4.6	1283
6.8	1697	4.8	1184	5.0	1004	5.3	1347	5.0	1358
6.4	1576	4.8	1244	4.7	1170	5.8	1126	5.5	1333

Nodular		Bedded		Laminated		Mottled		Replacement	
t	Srppm	t	Srppm	t	Srppm	t	Srppm	t	Srppm
6.7	1664	6.3	1587	4.3	1156	5.3	1283	5.4	1355
6.9	1743	6.5	1607	4.7	1217	5.2	1313	5.5	1177
6.5	1652	6.4	1562	4.3	1117	5.0	1263	4.4	1275
5.7	1457	6.2	1516			4.9	1255	4.9	1265
5.8	1458	6.7	1641			5.0	1291	5.0	1252
5.5	1375	6.6	1578			4.6	1146	4.9	1237
5.9	1502	6.5	1570			4.3	1196	4.9	1303
6.3	1574	6.2	1520			5.7	1401	5.1	1312
5.7	1457	5.6	1339			4.7	1214	5.3	1231
6.3	1610	6.2	1502			4.2	1053	6.0	1303
6.6	1625	4.9	1247			4.5	1122	5.3	1201
6.7	1698	5.5	1440			5.1	1291	4.1	1075
6.6	1660	6.8	1194			4.7	1191	3.1	1114
6.1	1556	5.5	1403			3.6	1003	2.7	763
5.8	1510	5.1	1321			5.1	1255	2.6	760
6.6	1615	5.0	1393			4.0	1009	0.6	350
5.6	1441	5.0	1315			3.4	933	1.0	468
5.3	1357	5.2	1265			5.1	1271	4.6	1133
Sr Mean -		Sr Mean -		Sr Mean -		5.3	1335	4.4	1177
1606		1397		1190		5.8	1467	4.4	1128
t Mean -		t Mean -		t Mean -		5.1	1325	4.0	1050
6.5		5.7		4.9		5.5	1360	3.1	851
						5.5	1403	1.9	665
						6.5	1649	3.7	1020

Nodular		Bedded		Laminated		Mottled		Replacement	
t	Srppm	t	Srppm	t	Srppm	t	Srppm	t	Srppm
						5.7	1603	3.8	1023
						3.6	1125	1.7	635
						5.3	1351	1.6	558
						5.2	1316	3.4	942
						5.4	1383	4.5	1139
						5.2	1371	5.4	1450
						Sr. Mean -		Sr. Mean -	
						1256		1135	
						q Mean -		q Mean -	
						4.9		4.3	

APPENDIX D

Relative Ages of Salt Solution Structures

RELATIVE AGES OF THE SALT SOLUTION STRUCTURES

The isopach maps presented in this thesis, supplemented by similar maps from published accounts of formations overlying the Saskatchewan Group may be employed to determine the relative ages of the various salt solution structural elements. Solution collapse structures may have had relatively long and complex stages of development, but there is remarkably close agreement among workers on their relative ages. Walker (1957) concluded that the earliest stage of salt removal was during Middle Devonian times. During this event salt solution was restricted to local solution channels. According to Walker (1957) the major periods of solution were during Mississippian to Triassic, and post-Jurassic times. He postulated that the latter stage was the time when almost all of the salt covering the Swift Current platform was removed. Sawatzky et al. (1960) proposed that salt solution began on a localized basis during Late Devonian time, but the dominant events occurred during Mississippian to early Jurassic and Late Cretaceous to post-Cretaceous time. Christopher (1961) presented the thesis that salt removal was associated with periods of prolonged subaerial erosion, i.e., Late Mississippian to Middle Jurassic, Late Jurassic to Early Cretaceous, Cenozoic and Quarternary. Wilson et al. (1963, pp. 14-16) in a discussion of the evolution of the structural feature underlying the Outlook oilfield of Montana, also postulated four periods of salt solution; Upper Devonian, Mississippian to Jurassic, Jurassic and Late Cretaceous.

In the opinion of the author the salt solution features present in the map area evolved over a prolonged period of geologic time

extending from late Middle Devonian to Latest Cretaceous or Early Tertiary. Removal of the salt was not continuous, however, and was, in fact, interrupted by relatively long periods during which no perceptible amounts of salt were removed. The earliest events were confined to narrow local channels, but as solution progressed the channels broadened and in time coalesced producing the generally prominent escarpment marking the present edge of the Prairie Evaporite Formation (Figure 28). The writer is of the opinion that the earliest period of salt removal in the map area, may be inferred from the isopach map of unit A (First Red Beds) in the Davidson Member of the Souris River Formation (Lane, 1964 - Figure 13). Lane's map shows that his unit A thickens in the Elbow Sub-basin and the Rosetown Embayment. The second stage of salt solution appears to have taken place in Late Devonian time. Collapse of the overlying strata into the solution channel must have taken place during the time the sediments of the Seward and Wymark Members of the Duperow Formation were being deposited (Figure 13 and 14). At this time solution and accompanying collapse recurred in the Elbow sub-basin and was initiated in the Maple Creek, Midway, Birsay-Lawson, Bladworth and Saskatoon Embayments, and in the Swift Current sink (Figure 28). Latest Devonian to Early Mississippian solution was restricted to the Elbow sub-basin and its attendant embayments as illustrated by the isopach maps of the Torquay, Big Valley and Bakken Formation of the Devono- Mississippian Three Forks Group of Christopher (1961). Sawatzky _et al_. (1960) suggested that local thickening of the post-Mississippian pre-Middle Jurassic Watrous Formation may be interpreted as the product of salt removal during Mississippian to Early Jurassic times. The last stage of salt removal was probably

post-Cretaceous and appears to have recurred in some of the earlier solution areas (Bladworth and Saskatoon embayments and the Elbow Sub-basin), because the strata including latest Cretaceous beds overlying these collapse areas have been flexed into homoclinal and synclinal structures.

APPENDIX E

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Selected Core Descriptions

Tidewater Parkbeg Crown No. 1

Lsd. 10-32-18-3W3

K.B. 2217

Cored Interval:	-	4561 feet - 4825 feet
Overlying Beds	-	Big Valley Formation
Top of Torquay Formation		4428 feet below K.B.
Drilled Depth in Feet -		
4561 - 4566	-	Mudstone - medium olive gray; calcareous; earthy; compact. Contains a 2.5 inch thick bed of coarse to medium-grained calcarenite composed of rounded carbonate rock and organic fragments. Also present are yellowish olive gray and reddish brown shale stringers and two thin beds 0.4 - 1.25 inch of very fine-grained, grainy, light olive gray, argillaceous dolomite with stringers of carbonaceous material.

Top of Upper Member (Birdbear Formation) - 4566 feet below K.B.

4566-4566.5	-	Dolomite - microcrystalline; medium brownish gray; argillaceous with olive gray calcareous shale stringers.
4566.5-4571.5	-	Dolomite - microcrystalline; medium greenish gray with brown mottling; some thin shaly beds which have been contorted. The rock is in part anhydritic with light gray

	-	crystals growing in the interstices.
4571.5 - 4572.1	-	Limestone - cryptocrystalline; fractured; very pale orange; slightly dolomitic; argillaceous; containing small rounded granules of white to clear anhydrite.
4572.1 - 4576.0	-	Dolomite - microcrystalline; sucrosic; pale yellowish brown; fracturing and microfaulting present; thinly bedded with carbonaceous material along bedding surface. Anhydrite fills fractures and is also present in the form of grayish white translucent blebs.
4576.0 - 4577.2	-	Anhydrite - cryptocrystalline; light gray to medium dark gray; patches of dolomite with partings of carbonaceous material at the anhydrite-dolomite interfaces.
4577.2 - 4583.2	-	Dolomite - microcrystalline; sucrosic; pale yellowish brown; argillaceous; poorly developed bedding with thin hairline partings of carbonaceous material. Scattered pyrite crystals.
4583.2 - 4584.2	-	Anhydrite - cryptocrystalline; light to medium dark gray; some patches of dolomite with partings of carbonaceous material at the anhydrite - dolomite interfaces.

4584.2 - 4589.5 - Dolomite - cryptocrystalline; argillaceous; very pale orange; pelletoid in part. Becomes somewhat anhydritic towards the base of the interval.

4589.5 - 4619.0 - Limestone - microcrystalline; sucrosic; very pale yellowish brown with pale yellowish brown mottling; dolomitic. Some blebs of grayish white, translucent anhydrite present. Stromatolitic material which may be algal near the base of the interval.

Top of lower member (Birdbear Formation) - 4619.0 feet below K. B.

4619.0 - 4653.0 - Limestone - microcrystalline; sucrosic; very pale yellowish brown with pale yellowish brown mottling; dolomitic, slightly argillaceous.

Top of Subunit B-3 Seward Member (Duperow Formation) - 4653 feet below K. B.

4653.0 - 4664.0 - Shale - dark greenish gray; waxy; calcareous; flaky; with more massive, grayish red; calcareous shale toward base. Grayish red shale contains reddish stained white crystalline anhydrite blebs.

Subunit B-2

4664.0 - 4665.1 - Anhydrite - microcrystalline; massive; pale

yellowish brown.

4665.1 - 4668.1	-	Limestone - cryptocrystalline to microcrystalline; poorly bedded in part with thin carbonaceous partings along bedding surface; very pale yellowish brown; pellets and fragmented fossil remains in lower portions. Dusky yellowish brown anhydrite porphyroblasts disseminated through the interval.
4668.1 - 4670.2	-	Dolomite - cryptocrystalline; massive; mottled very pale yellowish brown to pale yellowish brown; calcitic. Becomes more calcareous and argillaceous toward base of interval.
4670.2 - 4671.0	-	Anhydrite - microcrystalline; light medium gray; banded; strong intermixing of calcareous material.
4671.0 - 4676.7	-	Dolomite - microcrystalline; sucrosic; massive; very pale yellowish brown to pale yellowish brown; argillaceous; scattered dusky yellowish brown anhydrite crystals and blebs of grayish white translucent anhydrite.
4676.7 - 4687.0	-	Dolomite - microcrystalline; massive; light gray to light olive gray; slightly argil-

laceous; scattered blebs of bluish white, translucent anhydrite and also clear crystals of anhydrite.

Subunit B1

4687.0 - 4696.7	-	Dolomite - microcrystalline; light olive gray; argillaceous with scattered blebs of bluish white translucent anhydrite and clear crystals of anhydrite.
4696.7 - 4703.7	-	Limestone - microcrystalline; medium light gray; pinch and swell structures developed with partings of carbonaceous shale developed around nodules of limestone. The nodules range in size from 0.3 inch to 1.5 inches long. Some scattered brachiopod remains. Bluish white anhydrite is present in long circular tubes which appear to be relicts of corals.
4703.7 - 4712.0	-	Limestone - microcrystalline; massive; medium olive gray; numerous whole and fragmental fossil remains including corals, brachiopods, ostracods and crinoid columnals; argillaceous.
4712.0 - 4743.5	-	Limestone - microcrystalline, olive gray; indistinct bedding for the most part; extremely argillaceous; fossil debris is mainly crinoid

		columnals, and burrows. Some beds contain thin layers of less argillaceous limestone which have been effected by compaction as seen from the pinch and swell phenomenon present.
4743.5 - 4744.4	-	Limestone - microcrystalline; brownish olive gray; contains abundant crinoid columnals, and brachiopod and ostracod remains; argillaceous and dolomitic.
4744.4 - 4744.9	-	Limestone - microcrystalline; dark olive gray; extremely argillaceous.
Unit A		
4744.9 - 4746.5	-	Limestone - microcrystalline; pale yellowish brown to olive gray in part mottled; with several patches of finely comminuted fossil material. Thin partings of dusky yellowish brown carbonaceous stringers are common, some disseminated pyrite and crystal encrustations associated with the shale partings.
4746.5 - 4749.6	-	Dolomite - microcrystalline; olive gray; pyrite replacement of the rock along a vertical fracture, massive.
4749.6 - 4750.4	-	Anhydrite - microcrystalline; bedded near top; otherwise massive; medium gray.

4750.4 - 4750.8 - Limestone - microcrystalline; pelletoid, light olive gray with stringers of carbonaceous material and disseminated pyrite.

4750.8 4752.7 - Dolomite - microcrystalline; massive; pale orange brown; slightly argillaceous; some fractures and vugs filled by anhydrite.

4752.7 - 4756.8 - Limestone - microcrystalline; with indistinct bedding; light to medium gray; extremely argillaceous. Patches of rounded to subrounded carbonate distributed through lower part of interval. Rock is fractured to some extent with some evidence of minor vertical movement.

4756.8 - 4768.0 - Anhydrite - microcrystalline; vitreous luster; moderate yellowish brown with inclusions of moderate yellowish brown, microcrystalline, sucrosic dolomite which impart the typical mottled or mosaic appearance to the anhydrite. Some carbonaceous partings at the dolomite-anhydrite interfaces. Stringers of quartz are dispersed through the anhydrite.

4768.0 - 4768.5 - Dolomite - cryptocrystalline; very pale orange; extremely argillaceous. Rock is fracture with anhydrite filling the fractures.

4768.5 - 4770.6	-	Dolomite - microcrystalline; poorly bedded; very pale orange to pale yellowish brown; slightly argillaceous. Carbonaceous material common along bedding surface. Some microfolding of bedding in lower portion of interval.
4770.6 - 4773.2	-	Marlstone - medium olive gray; highly calcareous; massive. Some microfolding present.
4773.2 - 4775.7	-	Anhydrite - microcrystalline; massive; dusky yellowish brown with pale yellowish brown dolomite inclusions particularly near base.
4775.7 - 4777.5	-	Dolomite - cryptocrystalline; very pale orange; argillaceous.
4775. - 4779.0	-	Limestone - microcrystalline; pale yellowish brown; massive; dusky yellowish brown and white anhydrite crystals dispersed through rock.
4779.0 - 4784.0	-	Marlstone - light gray to olive gray; calcareous; massive. Thin intraformational breccia at the top and bottom of the interval consisting of subangular fragments 1/8 - ½ inch in diameter.

4784.0 - 4787.0	-	Anhydrite - microcrystalline; thinly bedded; dark yellowish brown; sharp contact with underlying and overlying strata.
4787.0 - 4788.0	-	Dolomite - cryptocrystalline; pale yellowish brown to dark yellowish brown; thinly laminated grades into more massive argillaceous limestone toward base of interval.
4788.0 - 4796.9	-	Limestone - microcrystalline; pellets and fossil debris; very pale orange to pale yellowish brown; highly fractured and brecciated. Interstices of breccia filled with white crystalline anhydrite.
4796.9 - 4803.1	-	Marlstone - light gray; highly calcareous; compact contains intraformational breccia and partings of carbonaceous material.
4803.1 - 4803.6	-	Anhydrite - microcrystalline; thinly bedded; pale yellowish brown.
4803.6 - 4804.1	-	Dolomite - cryptocrystalline; pale yellowish brown; poorly bedded; argillaceous; anhydritic in upper portion.
4804.1 - 4805.8	-	Limestone - microcrystalline; massive; contains pellets, algal nodules and other unidentifiable fossil detritus; pale yellowish

brown; disseminated anhydrite crystals.

4805.8 - 4807.0	-	Marlstone - light gray; compact; poorly bedded in part grades to argillaceous limestone toward base which contains pinch and swell structures - limestone nodules and carbonaceous shale partings.
4807.0 - 4807.9	-	Anhydrite - microcrystalline; massive; pale yellowish brown.
4807.9 - 4808.2	-	Dolomite - cryptocrystalline; pale yellowish brown; massive; argillaceous; anhydritic in upper portion.
4808.2 - 4813.9	-	Limestone - microcrystalline; thinly bedded with carbonaceous material along bedding surface; contains pellets and fossil debris (brachiopods and pelecypods).

Top of the Wymark Member (Duperow Formation) - 4813.9 feet below K.B.

4813.9 - 4825.0	-	Anhydrite - pale yellowish brown to light gray; nodular in part mainly mottled with inclusions of microcrystalline pale yellowish brown dolomite, anhydrite is microcrystalline.

Cored Interval: 4862.0 feet - 4867.0 feet

4862.0 - 4867.0	-	Limestone - cryptocrystalline; pale yellowish brown; argillaceous; massive; grades

- into dark gray, marlstone at base.

Top of Elstow Member (Duperow Formation) - 5220 feet below K. B.

Tidewater Imperial Elbow Crown #2

Lsd. 5-13-23-6W3

K.B. 1982

Cored Interval: - 3785 feet - 3801 feet.

Overlying beds - Torquay Formation

Top of Upper Member (Birdbear Formation) - 3766 feet below K. B.

Drilled Depth in feet -

3785 - 3788 - Limestone - cryptocrystalline; ovoid pellets between 0.28 and 0.56 mm. in diameter; poor porosity; mottled moderate yellowish brown to very pale orange; massive; dolomitic.

3788 - 3793 - Dolomite - microcrystalline; fair intergranular porosity; very pale orange; thinly bedded; calcitic.

3793 - 3801 - Dolomite - microcrystalline; sucrosic; good intergranular porosity; pale yellowish brown; massive, but with some fracturing healed by finely disseminated pyrite.

Top of Lower Member (Birdbear Formation) - 3815 feet below K.B.

- Cored Interval: 4310 feet - 4343 feet.

Top of Wymark Member (Duperow Formation) - 4050 feet below K.B.

4310 - 4322 - Anhydrite - microcrystalline; dense; colour varies from white through dark yellowish orange to moderate and pale yellowish brown; massive to poorly bedded; stringers and

- streaks of microcrystalline sucrosic dolomite.

4322 - 4332 - Dolomite - microcrystalline; sucrosic; fair pin point and intergranular porosity; pale yellowish brown; massive; large amounts of very finely disseminated pyrite.

4332 - 4343 - Anhydrite - microcrystalline; dense; colour varies as in 4310-4322; mainly massive but with thin interbeds of very pale orange, anhydritic dolomite over the interval 4335.5 - 4336.

Top of the Elstow Member (Duperow Formation) - 4464 feet below K. B.

Panamerican A-1 West Saskatoon 14-10

Lsd. 14-10-35-7W3

K.B. 1725

Cored Interval:	-	2452 feet - 2502 feet
Overlying beds	-	Seward Member (Duperow Formation)
Top of Wymark Member	-	(Duperow Formation) - 2376 feet below K.B.
Drilled Depth in Feet	-	
2452.0 - 2459.1	-	Limestone - microcrystalline; poor porosity; pale yellowish brown; alternating beds of ovoid to irregularly-shaped pellets, 0.06 mm. to 0.12 mm., and carbonate ooze with remains of brachiopods and ostracods; high carbonaceous contain.
2459.1 - 2460.0	-	Limestone - microcrystalline; sucrosic with dolomite rhombs in a sucrosic matrix; pale yellowish brown; massive to poorly laminated scattered brachiopod remains; large amounts of carbonaceous material and disseminated pyrite.
2460 - 2502.0	-	Limestone - microcrystalline; sucrosic with dolomite rhombs in sucrosic matrix; pale yellowish brown; alternating sequence of poorly laminated and markedly laminated strata; scattered brachiopod remains; large amounts of carbonaceous material particularly along

- interlaminar surfaces; some disseminated pyrite.

Top of Elstow Member (Duperow Formation) - 2671 feet below K.B.

Sohio Standard Langham No. 1

Lsd. 9-18-40-7W3

K.B. 1689

Cored Interval: - 1937 feet - 1947 feet

Overlying beds - Cretaceous - Mannville Formation

Top of the Wymark Member - (Duperow Formation) - 1905 feet below K.B. (Erosional).

Drilled Depth in Feet -

1937.0 - 1946.0 - Dolomite - microcrystalline; light to dark gray; massive; very argillaceous.

1946.0 - 1947.0 - Limestone - cryptocrystalline; contains ovoid pellets, 0.26 mm. to 0.52 mm. in diameter; pale yellowish brown; dolomitic with some scattered clear anhydrite crystals.

Top of Elstow Member (Duperow Formation) - 2187 feet below K.B.

Cored Interval: - 2283 feet - 2303 feet

Top of Saskatoon Member (Duperow Formation) - 2230 feet below K.B.

2283 - 2285.8 - Dolomite - microcrystalline; light gray to yellowish gray; massive; very argillaceous.

2285.8 - 2287.7 - Dolomite - cryptocrystalline; yellowish gray; scattered unidentifiable fossil remains; has fractures and incipient stylolites; calcitic. Pockets of ovoid pellets 0.15 mm. in diameter in lower portion.

2287.7 - 2291.3 - Dolomite - microcrystalline to crypto-crystalline; pale yellowish brown to very pale orange; carbonaceous shale partings in upper portion; somewhat argillaceous toward the base of the interval.

2291.3 - 2296.6 - Limestone - microcrystalline to crypto-crystalline; pale yellowish brown; concentrations of brachiopod and gastropod shells and crinoid columnals. Vugs are present which appear to be solutioned fossil remains, the vugs are lined with calcite crystals. Some pinch and swell structures - limestone nodules surrounded by carbonaceous shale partings.

2296.6 - 2301.4 - Limestone - cryptocrystalline; patches of brachiopod remains, also lithoclasts of irregular shape between 2.0 mm. and 8.0 mm in diameter outlined by finely disseminated pyrite. Rock is very pale yellowish brown, dolomitic, and has incipient stylolite development.

2301.4 - 2303.0 - Dolomite - microcrystalline; brecciated consisting of subangular fragments 1.0 mm. to 6.0 mm. in diameter; yellowish gray with very pale orange fragments.

Top of Souris River Formation - 2304 feet below K.B.

Tidewater Birsay Crown No. 1

Lsd. 13-4-25-8W3

K.B. 2160

Cored Interval:	-	3844 feet - 3894 feet
Overlying beds	-	Upper Member of the Birdbear Formation
Top of Lower Member	-	(Birdbear Formation) - 3832 feet below K.B.
Drilled Depth in Feet	-	
3844.0 3846.8	-	Dolomite - microcrystalline; sucrosic with patches of rhombic dolomite; fair intergranular porosity; moderate yellowish brown to dark yellowish brown; argillaceous; some ovoid to irregularly-shaped lithoclasts up to 6 mm. in diameter often encrusted by finely disseminated pyrite.
3846.8 - 3847.5	-	Dolomite - cryptocrystalline; fair porosity; medium yellowish brown; argillaceous; sedimentary boudinage; some lithoclasts encrusted by finely disseminated pyrite.
3847.5 - 3848.0	-	Dolomite - cryptocrystalline; remains of brachiopods, ostracods and gastropods; medium yellowish brown; argillaceous.
3848.0 - 3848.5	-	Shale - dusky yellowish brown; highly carbonaceous and very calcareous; organic remains include lingulid brachiopods, tentaculitids,

	-	scolecodonts and sporomorphs; laminated with alternating laminae of microcrystalline limestone.
3848.5 - 3850.0	-	Limestone - cryptocrystalline; fossil are mainly brachiopods; some ovoid to irregularly - shaped lithoclasts encrusted by finely disseminated pyrite.
3850 - 3850.5	-	Shale - brownish black; very calcareous and highly argillaceous; contains tentaculitids, lingulid brachiopods, scolecodonts, conodonts and sporomorphs; burns quite readily; some "pinch and swell" structures.
3850.5 - 3856.6	-	This next 6.1 feet is an alternating sequence of cryptocrystalline limestone and brownish black, highly carbonaceous and very calcareous shale similar to those described above. The beds of limestone and shale range between 0.3 feet and 0.6 feet thick.
3856.6 - 3859.7	-	Limestone - cryptocrystalline; contains brachiopods; fair intergranular porosity; pale yellowish brown; has lenses of olive gray, very argillaceous limestone.
3859.7 - 3871.7	-	Dolomite - microcrystalline; sucrosic to rhombic; thinly bedded - alternating dark

- and light layers, the darker ones contain large amounts of carbonaceous material.

3871.7 - 3894.0 - Breccia - subangular to subrounded limestone fragments 0.23 mm. to 26.0 mm. in diameter in a grayish red to pale reddish brown, compact mudstone matrix. Fragments are mainly micro-crystalline, laminated, dolomitic limestone.

Cored Interval: - 3904 feet - 3954 feet

3904.0 - 3907.0 - Dolomite - cryptocrystalline; dense; olive gray.

Top of Seward Member (Duperow Formation) - 3907.0 feet below K.B.

3907.0 - 3912.0 - Dolomite - microcrystalline; sucrosic; good intergranular porosity; slightly argillaceous; medium yellowish brown.

3912.0 - 3918.8 - Breccia - subangular to subrounded limestone and dolomite fragments in moderate yellowish brown to dark grayish green, compact mudstone matrix. Fragments consist of microcrystalline, sucrosic dolomite or argillaceous limestone.

3918.8 - 3926.0 - Dolomite - microcrystalline, sucrosic to rhombic; very good intergranular porosity; grayish yellowish orange; white sucrosic

	- anhydrite filling some void spaces; incipient stylolites in lower portion of interval.
3926.0 - 3930.5	- Limestone - microcrystalline; poor porosity; light gray; thinly laminated, alternating with laminae of very fine-grained sucrosic limestone; some laminae strongly contorted; very argillaceous.
3930.5 - 3954.0	- Dolomite - microcrystalline; sucrosic; good intergranular porosity; moderate yellowish brown; fractured with white anhydrite along the fracture surfaces.

Top of Wymark Member (Duperow Formation) - 4155 feet below K.B.

Tidewater Birsay Crown #2

Lsd. 4-15-25-8W3

K.B. 2067

Cored Interval:	-	3759 feet - 3781 feet
Overlying beds	-	Torquay Formation
Top of Upper Member		(Birdbear Formation) - 3720 feet below K.B.
Drilled Depth in Feet	-	
3759 - 3762	-	Dolomite - microcrystalline; poor porosity; but with some pin point vugs; pale yellowish brown; massive, some vertical fracturing; intermittent intervals with small, rounded blebs of white, fibrous anhydrite dispersed through dolomite, blebs 1.0 to 7.0 mm. in diameter.
3762 - 3772	-	Dolomite - cryptocrystalline; good intergranular porosity in upper portion poor below that; moderate yellowish brown to yellowish gray; poorly laminated with thin partings of carbonaceous material.
3772 - 3779	-	Limestone - cryptocrystalline; fair pin point porosity in upper 2 feet poor below; yellowish gray to light olive gray; poorly laminated with thin partings of carbonaceous material; patches of dolomite rhombohedrons

dispersed through rock; dolomitic.

3779 - 3781 - Limestone - cryptocrystalline; fragmental (lithoclasts or pellets?) poor porosity, but some scattered vugs; moderate yellowish brown; massive.

Top of Lower Member (Birdbear Formation) - 3787 feet below K.B.

Imperial Dinsmore 1-32-27-11

Lsd. 1-32-27-11W3

K.B. 1969

Cored Interval:	-	3805 feet - 3912 feet
Overlying beds	-	Seward Member (Duperow Formation)
Top of Dinsmore Evaporite		Wymark Member (Duperow Formation) - 3803 feet below K.B.
Drilled Depth in Feet	-	
3805 - 3835.4	-	Anhydrite - cryptocrystalline; dense; dusky yellowish brown with occasional thin stringers of dolomite. Becomes light gray and crystalline toward the bottom of the interval. (Base of Dinsmore Evaporite).
3835.4 - 3841.7	-	Dolomite - cryptocrystalline; dense; yellowish gray; calcitic; laminated with thin carbonaceous shale partings in the upper portion. Some sedimentary boudinage developed in the lower portion of this interval. Disseminated pyrite is common in the rock.
3841.7 - 3842.2	-	Shale - medium gray; calcareous; splintery; calcite filled fractures. Patches of microcrystalline; light gray limestone.
3842.2 - 3843.2	-	Limestone - cryptocrystalline; dolomitic; yellowish gray. Unidentifiable shell fragments are common.

3843.2 - 3843.4	- Dolomite - microcrystalline; dense; very pale orange; anhydritic.
3843.4 - 3844.8	- Anhydrite - microcrystalline; dense; light gray; with very pale orange, cryptocrystalline stringers of dolomite.
3844.8 - 3845.6	- Dolomite - cryptocrystalline; very pale orange; with pellets ranging from 0.2 mm. to 0.26 mm.
3845.6 - 3848.9	- Anhydrite - microcrystalline; dense; light gray; with very pale orange, cryptocrystalline stringers of dolomite.
3848.9 - 3855.0	- Dolomite - microcrystalline; very pale orange; with pellets ranging from 0.2 mm. to 0.26 mm.
3855.0 - 3881.5	- Anhydrite - cryptocrystalline; light gray to dusky yellowish brown; with stringers and patches of microcrystalline; very pale orange dolomite. In the lowermost 1.5 feet the anhydrite has a pronounced bedded appearance.
3881.5 - 3882.5	- Dolomite - cryptocrystalline; dense; yellowish gray to pale yellowish brown; thinly bedded with carbonaceous material along bedding surfaces.

3882.5 - 3887.6 - Limestone - cryptocrystalline; pellets and intraclasts ranging between 0.8 mm. and 5.7 mm., ovoid to globular in shape; fossil fragments near the base of the interval; pale yellowish brown; with incipient stylolite development and some sedimentary boudinage where there are thick beds of carbonaceous shale.

3887.6 - 3891.6 - Shale - medium light gray; calcareous; compact.

3891.6 - 3895.6 - Limestone - cryptocrystalline; highly fossiliferous in lower 3 feet including corals, brachiopods, gastropods and algal nodules up to 18 mm. in diameter; also some ovoid to globular pellets, 0.8 mm. to 1.04 mm. in diameter; very pale orange to pale yellowish brown; slightly argillaceous particularly at the top of the interval; dolomitic.

3895.6 - 3896.1 - Dolomite - microcrystalline; poor porosity; yellowish gray; argillaceous; with finely disseminated and cubic pyrite.

3896.1 - 3897.0 - Shale - medium dark gray; slightly calcareous; sooty appearing; platy; brittle; with thin microcrystalline, dolomite near base and passing into 2 inch thick microcrystalline,

light gray anhydrite.

3897.0 - 3902.0	-	Limestone - cryptocrystalline; poor porosity; dark yellowish brown to yellowish gray; poorly laminated in part; and with ovoid to globular pellets up to 0.26 mm. in diameter in the lower portion.
3902.0 - 3902.6	-	Dolomite - cryptocrystalline; fair to good inter-granular porosity; yellowish gray; slightly argillaceous.
3902.6 - 3906.8	-	Anhydrite - cryptocrystalline; dense; olive gray; thinly bedded.
3906.8 - 3907.8	-	Shale - dark greenish gray, slightly calcareous; waxy appearance; splintery; with thin lenses of white crystalline anhydrite in the lower 6 inches.
3907.8 - 3913.8	-	Anhydrite - cryptocrystalline; dense; medium dark gray to white with dusky yellowish brown patches; thinly bedded at the top becoming massive with patches of microcrystalline, pale yellowish brown, dolomite.

Top of the Elstow Member (Duperow Formation) 4190 feet below K.B.

Ceepee Riley Lake No. 3-4

Lsd. 3-4-39-13W3

K.B. 2385

Cored Interval:	-	2548 feet - 2568 feet
Overlying beds	-	Upper Member (Birdbear Formation)
Top of Lower Member	-	(Birdbear Formation) - 2467 feet below K.B.
Drilled Depth in Feet	-	
2548.0 - 2551.0	-	Limestone - microcrystalline; light gray to light olive gray; massive; argillaceous to very argillaceous toward base of interval.
2551.0 - 2553.0	-	Limestone - microcrystalline; light gray; bedded - bedding surfaces show incipient "pinch and swell" structural development; argillaceous.

Top of Seward Member (Duperow Formation) - 2553 feet below K.B.

2553.0 - 2565.0	-	Breccia - matrix consists of light olive gray; very calcareous, hard, shaly material; fragments are angular to subangular, 1.0 mm. to 30.0 mm. in diameter, microcrystalline, sucrosic to rhombic, light gray dolomite.
2565.0 - 2566.0	-	Dolomite - microcrystalline; sucrosic to rhombic; medium olive gray, poorly bedded.
2566.0 - 2567.0	-	Limestone - cryptocrystalline; finely

comminuted fossil debris and pellet material; moderate yellowish brown; massive; dolomitic. Grades into microcrystalline, light gray to yellowish gray brecciated dolomite at base.

2567.0 - 2568.0 - Dolomite - microcrystalline; sucrosic; pale yellowish brown to yellowish gray. Maybe slightly argillaceous in part. Some light oil-staining.

Top of Wymark Member (Duperow Formation) - 2768 feet below K.B.

Cored Interval: - 3090 feet - 3115 feet

3090.0 - 3094.0 - Limestone - cryptocrystalline; medium dark gray; argillaceous.

Top of Elstow Member (Duperow Formation) - 3094 feet below K.B.

3094.0 - 3100.0 - Marlstone - medium dark gray; very calcareous; massive; hard with some flat, well-rounded to subrounded, ¼ inch to ½ inch pebbles in lower part of the interval.

3100.0 - 3104.0 - Limestone - cryptocrystalline; contains abundant fossil remains mainly brachiopods (Atrypa spp. and Eleutherokomma sp.) but with some bryozoa and algal growths encrusting some of the other fossil debris; olive gray; massive.

3104.0 - 3115.0 - Marlstone - medium light gray; very

calcareous; massive; hard; scattered fossil remains. A flat pebble conglomerate similar to those described from the core of the Calstan Fort Pitt 1-25 well (Lsd. 1-25-54-26W3) is present at a depth of 3111.0 feet.

Top of Saskatoon Member (Duperow Formation) - 3140 feet below K.B.

Tidewater Duperow Crown No. 1

Lsd. 4-9-35-16W3

K.B. 2291

Cored Interval:	-	2678 feet - 2766 feet.
Overlying beds	-	Cretaceous-Mannville Formation
Top of Three Forks Group	-	(Eroded) - 2598 feet below K.B.
Drilled Depth in Feet	-	
2678.0 - 2686.0	-	Limestone - microcrystalline; brecciated and highly disturbed; moderate reddish orange to pale red with very pale green, soft, shale fragments. There are thin beds of pellets in a marly matrix in the basal part of the interval.

Top of the Upper Member (Birdbear Formation) 2686 feet below K.B.

2686.0 - 2687.7	-	Limestone - microcrystalline; poorly bedded; pale green to medium gray; pellets between 0.5 mm. to 1.0 mm. in diameter which are predominantly in the pale green parts of the rock.
2687.7 - 2688.8	-	Shale - pale green; very calcareous; interbedded with brownish fine-grained to medium-grained limestone. Some "pinch and swell" structures present.
2688.8 - 2695.6	-	Limestone - microcrystalline; poorly bedded

to thinly bedded; yellowish gray to light olive gray; slightly argillaceous; some finely disseminated pyrite along bedding planes; thin partings of pale green, calcareous shale.

2695.6 - 2705.0 - Dolomite - cryptocrystalline; good vuggy and intergranular porosity; light olive gray; calcispheres; some dead oil staining. Finely disseminated pyrite dispersed through rock and pyrite crystals lining vug walls.

2705.0 - 2708.0 - Dolomite - microcrystalline; sucrosic; fair to good intergranular porosity and some vugs, some dead oil staining; pale yellowish brown; some brecciation with various coloured materials infilling fractures including dark gray calcite and pale green marl. Some reddish brown staining associated with the fractures also.

2708.0 - 2766.0 - Limestone - microcrystalline; sucrosic; good vuggy porosity; pale yellowish brown to yellowish gray; recrystallized fossil remains include algal nodules, corals and brachiopods; some vugs appear to be solutioned fossils; some tarry dead oil in vugs others are lined with calcite

crystals; dolomitic.

Cored Interval: - 2771 feet - 2817 feet

2771.0 - 2784.0 - Dolomite - microcrystalline; sucrosic; good intergranular and vuggy porosity; mottled yellowish gray to very pale orange; some coral and brachiopod remains.

2784.0 - 2791.0 - Dolomite - cryptocrystalline; good intergranular porosity; brecciated in part; yellowish gray; argillaceous; some finely disseminated pyrite.

Top of Lower Member -(Birdbear Formation) - 2791.0 feet below K.B.

2791.0 - 2804.0 - Dolomite - cryptocrystalline; fair intergranular porosity; poorly bedded; yellowish gray; very argillaceous; scattered unidentifiable fossil remains; some disseminated pyrite.

2804.0 - 2817.0 - Mudstone - light gray; very calcareous; compact; fossiliferous pockets containing gastropods, brachiopods and crinoid columnals; has the appearance of having been reworked - bedding is disrupted and burrows are present.

Cored Interval: - 2909 feet - 2940 feet

Top of Seward Member (Duperow Formation) - 2871 feet below K.B.

Core is from uppermost beds of subunit B1

2909.0 - 2923.0	-	Limestone - microcrystalline; poorly bedded; light olive gray; argillaceous; with highly fossiliferous beds containing mainly brachiopods and crinoid columnals.
2923.0 - 2926.0	-	Shale - medium light gray; calcareous; very fossiliferous mainly brachiopods and crinoid columnals; compact; flat, black, calcareous pebbles dispersed through the shale interval.
2926.0-2940.0	-	Limestone - microcrystalline; poorly bedded; light olive gray; argillaceous; with highly fossiliferous beds containing mainly brachiopods and crinoid columnals.
Cored Interval:	-	3025 feet - 3063 feet

Core is from the middle strata of unit A.

3025.0 - 3041.5	-	Marlstone - medium gray; very argillaceous; compact; poorly bedded; some unidentifiable fossil remains. Lower portion partly brecciated with anhydrite filling the interstices.
3041.5 - 3042.5	-	Anhydrite - microcrystalline; dusky yellowish brown; dense; with stringers of microcrystalline dolomite.

3042.5 - 3056.0	-	Limestone - cryptocrystalline; dense; thinly bedded with soft, dark brown, carbonaceous shale partings along bedding planes; light olive gray; dolomitic.
3056.0 - 3060.0	-	Limestone - cryptocrystalline to grainy; poor porosity; light olive gray; pellets 0.2 mm. to 0.9 mm., ovoid with black encrustation; some brachiopod remains.
3060.0 - 3063.0	-	Limestone - cryptocrystalline; dense thinly bedded with soft, dark brown, carbonaceous shale partings along bedded planes; light olive gray; dolomitic.
Cored Interval:	-	3160 feet - 3209 feet

Top of Wymark Member (Duperow Formation) - 3105 feet below K.B.

3160.0 - 3175.0	-	Limestone - cryptocrystalline; medium light gray to olive gray and yellowish gray; some crinoid columnals; thin carbonaceous shale partings impart laminated appearance to interval.
3175.0 - 3180.1	-	Limestone - cryptocrystalline to microcrystalline; patchy intergranular porosity; mottled medium olive gray to yellowish gray; lighter coloured areas slightly coarser grained; dolomitic.
3180.1 - 3195.3	-	Limestone - microcrystalline; poor porosity

some fracturing in upper 10 feet; pinch and swell structures in carbonaceous shale in lower 5 feet; medium olive gray to yellowish gray and dusky yellowish brown.

3195.3 - 3199.0	-	Dolomite - microcrystalline; good intergranular and pin-point porosity; thinly bedded; yellowish gray; argillaceous; thin carbonaceous shale partings some of which are contorted into microfolds.
3199.0 - 3202.5	-	Limestone - microcrystalline good intergranular porosity - some oil-staining; pale yellowish brown.
3202.5 - 3205.7	-	Dolomite - microcrystalline; fair vuggy porosity; olive gray; some poorly preserved and pyrite encrusted fossil remains; calcite crystals line the vugs.
3205.7 - 3209.0	-	Shale - medium gray; calcareous; fissile; interbedded with ½ inch thick beds of very fine-grained sublithographic, medium light gray, argillaceous dolomite.
Cored Interval:	-	3330 feet - 3365 feet
3330.0 - 3346.0	-	Anhydrite - microcrystalline; dense; dusky yellowish brown; with intermixed yellowish gray, very fine-grained, grainy, laminated

dolomite stringers and patches.

3346.0 - 3354.7	-	Limestone - microcrystalline; poor porosity; thinly laminated with carbonaceous shale partings; yellowish gray; thin anhydrite beds about 3" thick also scattered blebs.
3354.7 - 3356.3	-	Anhydrite - microcrystalline; dense; dusky yellowish brown.
3356.3 - 3363.8	-	Limestone - microcrystalline; poorly bedded to thinly bedded; carbonaceous shale partings where bedding well developed; fossils include brachiopods, pelecypods and algal nodules encrusting gastropod shells; very pale yellowish brown to yellowish gray; dolomitic.
3363.8 - 3365.0	-	Limestone - cryptocrystalline; "pinch and swell" structures common with internodular areas filled by highly argillaceous material; fossils are mainly brachiopods; yellowish gray.

Top of the Elstow Member - 3450 feet below K.B.

Cored Interval: - 3500 feet - 3545 feet.

Top of the Saskatoon Member (Duperow Formation) - 3498 feet below K.B.

3500.0 - 3506.0	-	Limestone - microcrystalline; fair pin-point and intergranular porosity; thinly bedded in part; pale yellowish brown; fossiliferous fragmental with patches of ovoid pellets between 0.26 mm. and 0.65 mm.
3506.0 - 3507.0	-	Limestone - cryptocrystalline; dense; laminated; olive gray with pale yellowish brown patches; argillaceous.
3507.0 - 3511.8	-	Anhydrite - microcrystalline; dusky yellowish brown; dense; thinly bedded with some interbedded dolomite; greater portion is nodular.
3511.8 - 3516.0	-	Limestone - microcrystalline; fair pin-point and intergranular porosity; laminated with carbonacecus material along interlaminar surfaces; yellowish gray; laminae crenulated into microfolds.
3516.0-3520	-	Anhydrite - microcrystalline; dusky yellowish brown; massive.
3520.8 - 3522.8	-	Limestone - cryptocrystalline; dense; laminated; pale yellowish brown; some intermixed anhydrite.
3522.8 - 3526.0	-	Anhydrite - microcrystalline; dusky

		yellowish brown to very light gray; massive.
3526.0 - 3527.3	-	Limestone - cryptocrystalline; dense; poorly bedded in part; light olive gray; slightly argillaceous.
3527.3 - 3532.3	-	Anhydrite - microcrystalline; dusky yellowish brown to very light gray; massive.
3532. - 3534.5	-	Limestone - cryptocrystalline; dense; mottled pale yellowish brown to dark yellowish brown; argillaceous; dark areas have acicular anhydrite crystals dispersed through them.
3534.5 - 3536.5	-	Mudstone - medium gray; calcareous; some unidentifiable fossil fragments; compact.
3536.5 - 3541.0	-	Limestone - cryptocrystalline; dense; poorly bedded to laminated; pale yellowish brown; anhydrite filled fractures and small blebs of anhydrite toward the base of the interval.
3541.0-3545.0	-	Limestone - cryptocrystalline; dense; pale yellowish brown; "pinch and swell" structures with dusky yellowish brown carbonaceous shale in the internodular areas.

Top of the Souris River Formation - 3592 feet below K.B.

Eagle Hills #1

Lsd. 8-10-40-16W3

K.B. 2389

Cored Interval:	-	2558 feet - 2601 feet
Overlying beds	-	Cretaceous-Mannville Formation
Top of Seward Member	-	(Duperow Formation) - 2592 (Erosional) feet below K.B.
Drilled Depth in Feet	-	
2592 - 2601	-	Limestone - cryptocrystalline; poor porosity; olive gray; massive; very argillaceous; becomes fossiliferous toward base, mainly highly comminuated shell fragments, also some spines and crinoid ossicles; some fractures in upper portion healed by pyrite.
Cored Interval:	-	2695 feet - 2715 feet
2695 - 2713	-	Limestone - cryptocrystalline; poor porosity; olive gray; poorly bedded; slightly argillaceous.
2713 - 2715	-	Limestone - cryptocrystalline; fossiliferous fragmental, remains included tabulate corals, brachiopod shells, calcispheres and carbonaceous flecks of unknown origin; poor porosity; yellowish gray; massive.

Top of Wymark Member (Duperow Formation) - 2740 feet below K.B.

Cored Interval:	-	2840 feet - 2861 feet
2840 - 2849	-	Limestone - cryptocrystalline; fossiliferous fragmental, remains include crinoid ossicles, brachiopod shells, calcispheres and carbonaceous fleck of unknown origin; poor porosity; yellowish gray; massive.
2849 - 2861	-	Marlstone - medium light gray; very calcareous; earthy; massive; compact; carbonaceous flecks dispersed through interval.
Cored Interval:	-	2878 feet - 2910 feet
2878 - 2885	-	Limestone - cryptocrystalline; poor porosity; pale yellowish brown; laminated with thin carbonaceous partings separating laminae.
2885-2894	-	Marlstone - yellowish gray; very calcareous; earthy; friable.
2894 - 2910	-	Limestone - cryptocrystalline; poor porosity; yellowish gray; laminated with thin carbonaceous partings separating laminae; very argillaceous.

Top of Elstow Member (Duperow Formation) - 3030 feet below K.B.

British American Cutknife Rutley 13-14-43-22

Lsd. 13-14-43-22W3

K.B. 2201.65

Cored Interval:	-	2212 feet - 2262 feet
Overlying beds	-	Cretaceous Mannville Formation
Top of Wymark Member	-	(Duperow Formation) - 2213 (Erosional) feet below K.B.
Drilled Depth in Feet	-	
2213 - 2214	-	Limestone - cryptocrystalline; highly comminuted fossil fragments (unidentifiable other than the large amount of ostracod remains); poor porosity, pale yellowish brown. Thin solution zones associated with large concentrations of carbonaceous material (appears to be an incipient or poorly developed stylolitic phenomenon).
2214 - 2220.7	-	Limestone - cryptocrystalline; pelletoid (irregularly-shaped, 0.1 - 1.00 mm. in diameter); some fossil debris (mainly algal remains); fair to good intergranular porosity; pale yellowish brown; massive to thinly laminated.
2220.7 - 2224	-	Limestone - cryptocrystalline with

dispersed calcite rhombohedra (.025 mm. across); fair intergranular porosity; pale yellowish brown; massive but with some vertical fractures infilled with argillaceous material.

2224-225.7 - Limestone - cryptocrystalline; algal growths associated with comminuted algal material; fair intergranular porosity; pale yellowish brown, massive.

2225.7 - 2234.4 - Limestone - cryptocrystalline; numerous fossil remains, often highly comminuted and unidentifiable, identifiable forms included, brachiopods, gastropods, pelecypods, ostracods, corals, stromatoporoids and spines; some pellets (distorted and 0.15 - 1.25 mm. in diameter); fair to poor porosity; pale yellowish brown; mainly massive but thinly bedded in the upper ½ foot with carbonaceous material along bedding surface. Some solution over stromatoporoids, as there are concentrations of carbonaceous material draped over them.

2234.4 - 2236.5 - Limestone - microcrystalline; fair intergranular porosity; very pale orange; massive.

2236.5 - 2245.7	-	Limestone - cryptocrystalline; some stromatolites; good intergranular porosity with dead oil-staining; very pale orange; some fracture brecciation.
2245.7 - 2251.5	-	Limestone - microcrystalline; fair to good intergranular porosity, lightly oil-stained; light gray; thinly laminated, vertical fractures in lower 2 feet infilled with clear to white crystalline anhydrite; argillaceous and in part dolomitic.
2251.5 - 2259	-	Limestone - microcrystalline; fair to good intergranular porosity, also scattered vugs; very pale orange; massive in part, some stromatolites and fracture brecciation.
2259 - 2262	-	Limestone - microcrystalline; oolites, ovoid, and distorted, 0.1 mm. in diameter; fair intergranular porosity; pale yellowish brown; massive; some scattered fossil remains.
Cored Interval:	-	2448 feet - 2491 feet
2448 - 2448.6	-	Limestone - cryptocrystalline; irregularly shaped pellets about 0.25 mm. in diameter; poor porosity; pale yellowish brown; massive; dolomitic.

2448.6 - 2450	-	Limestone - cryptocrystalline with scattered dolomite rhombohedrons about 0.027 mm. across; good intergranular porosity; very pale orange; mainly massive but poorly bedded in upper part; dolomitic.
2450. - 2452.5	-	Limestone - microcrystalline; stromatolites; poor porosity; medium yellowish brown; dolomitic.
2452.5 - 2461.8	-	Limestone - cryptocrystalline with large amounts of dolomite rhombohedrons ranging between 0.05 mm. and 0.125 mm. across; some stromatoporoids up to 90 mm. in diameter are associated with this lithology, particularly over the interval 2454-2457.6; fair intergranular porosity; pale to dark yellowish brown; poorly bedded to massive with some sedimentary boudinage in lower 4 feet; dolomitic.
2461.8 - 2462.7	-	Limestone - cryptocrystalline; poor porosity; dark yellowish brown; massive; dolomitic.
2462.7 - 2466.6	-	Limestone - very fine-grained; chalky, with scattered rhombic crystals 0.05 - 0.125 mm. across; fair intergranular porosity; pale yellowish brown; massive.

2466.6 - 2475.8	-	Limestone - microcrystalline; poor porosity; moderate yellowish brown; stromatolites; dolomitic.
2475.8 - 2486.6	-	Limestone - microcrystalline; with scattered dolomite rhombohedrons about 0.075 mm. across; stromatoporoids up to 90 mm. in diameter and some brachiopods (mainly *Atrypa* spp.); fair intergranular porosity; pale yellowish brown to moderate yellowish brown; massive; dolomitic.
2486.6 - 2490.3	-	Limestone - cryptocrystalline; irregularly-shaped pseudo-oolites, 0.1 to 0.375 mm. in diameter and lithoclasts in lower 1.3 feet composed of pseudo-oolites and up to 30 mm. across; fair intergranular porosity; pale to moderate yellowish brown; massive.
2490.3 - 2491	-	Limestone - cryptocrystalline with dolomite rhombohedrons 0.1 mm. across; fair intergranular porosity; poorly bedded; slightly dolomitic.

Top of Elstow Member (Duperow Formation) - 2567 feet below K.B.

Coleville Unit 5-30-31-23

Lsd. 5-30-31-23W3

K.B. 2350

Cored Interval:	-	3442 feet - 3447 feet.
Overlying beds	-	Seward Member (Duperow Formation)
Top of Wymark Member	-	(Duperow Formation) - 3413 feet below K.B.
Drilled Depth in Feet	-	
3442 - 3447	-	Marlstone - medium olive gray; very calcareous; earthy; massive; hard; scolecodont remains, some whole, others fragmented.
Cored Interval:	-	3465 feet - 3468 feet.
3465 - 3468	-	Limestone - cryptocrystalline matrix with 0.1 - 0.175 mm. rhombohedra; poor porosity; some poorly preserved fossil remains; pale yellowish brown; massive; dolomitic.

Top of Elstow Member (Duperow Formation) - 3950 feet below K.B.

Husky Phillips Eatonia #1

Lsd. 4-32-26-24W3

K.B. 2444

Cored Interval:	-	4090 - 4095 feet
Overlying beds	-	Seward Member (Duperow Formation)
Top of Wymark Member	-	(Duperow Formation) - 3852 feet below K.B.
Drilled Depth in Feet	-	
4090 - 4095	-	Halite - clear; well developed crystals; salty taste; vitreous luster.
Cored Interval:	-	4333 feet - 4338 feet
4333 - 4338	-	Anhydrite - cryptocrystalline; dense; light gray with yellowish gray tinge; thin stringers and streaks of microcrystalline, pale yellowish brown dolomite which impart a mosaic appearance to the anhydrite.
Cored Interval:	-	4357 feet - 4361 feet
4357 - 4358.8	-	Anhydrite - cryptocrystalline; dense; light gray with yellowish gray tinge; thin stringers and streaks of microcrystalline, pale yellowish brown dolomite which imparts a mosaic appearance to the anhydrite. Bed becomes increasingly dolomitic towards base.
4358.8 - 4361	-	Limestone - cryptocrystalline; poor porosity; very pale orange; thinly bedded with

partings of carbonaceous material along bedding surfaces. Sharp contact with overlying anhydrite.

Top of Elstow Member (Duperow Formation) - 4398 feet below K.B.

Canada Southern Buffalo Coulee #3

Lsd. 6-32-32-24W3

K.B. 2347

Cored Interval:	-	2915 - 2929 feet.
Overlying beds	-	Stettler Member, Three Forks Formation
Top of Upper Member	-	(Birdbear Formation) - 2952 feet below K.B.
Drilled Depth in Feet	-	
2915 - 2929	-	Anhydrite - microcrystalline; dense; dusky yellowish brown; intermixed and interbedded with cryptocrystalline, dense, pale yellowish brown dolomite, which often contains large amounts of secondary anhydrite.
Cored Interval:	-	2935 feet - 3018 feet.
2935 - 2947	-	Mudstone - greenish gray to dark greenish gray; earthy; slightly calcareous; massive; hard.
2947 - 2948	-	Limestone - microcrystalline; poor porosity; light olive gray; thinly bedded; very argillaceous.
2948 - 2952	-	Marlstone - medium light gray; dolomitic; earthy; massive to poorly laminated; hard.
2952 - 2969	-	Limestone - microcrystalline; fair intergranular porosity; medium olive gray to

olive gray; thinly laminated with carbonaceous material along bedding surfaces.

2969 - 2974	-	Limestone - microcrystalline; relict or ghost features which appear to have been pellets which were ovoid and up to 0.6 mm. in diameter; fair intergranular porosity; moderate yellowish brown; massive; dolomitic.
2974 - 3018	-	Limestone - microcrystalline; fossil remains present largely unidentifiable, but some atrypid brachiopods were observed; mainly poor porosity; medium olive gray; massive to poorly bedded; argillaceous becomes slightly argillaceous in lower 13 feet.
Top of Lower Member		(Birdbear Formation) approximately 3020 feet below K.B.
Total Depth	-	3018 feet below K.B.

Woods Paramount Luseland #13-32

Road Allowance West Boundary Sec 32-36-24W3

K.B. 2286

Cored Interval:	-	2540 - 2570 feet.
Overlying beds	-	Torquay Formation (Three Forks Group).
Top of Upper Member	-	(Birdbear Formation) - 2520 feet below K.B.
Drilled Depth in Feet	-	
2540 - 2555	-	Limestone - cryptocrystalline; poor porosity, but with scattered vugs in upper 3 feet; light olive gray; very argillaceous; interbedded with thin lenses and stringers of olive gray, very calcareous shale.
2555 - 2564	-	Limestone - microcrystalline; sucrosic; porosity dependent on grain size - very fine-grained, poor, fine-grained, good intergranular, latter heavily oil-stained, light olive gray; more argillaceous material associated with finer grained rock; some fracture brecciation.
2564 - 2570	-	Limestone - microcrystalline; poor porosity; light olive gray; very argillaceous; interbedded with lenses and stringers of olive gray, very calcareous shale.
Top of Lower Member		(Birdbear Formation) - 2623 feet below K.B.

Hudson Bay Denzil #4

Lsd. 16-6-39-24W3

K.B. 2268

Cored Interval:	-	2448 feet - 2481 feet.
Overlying beds	-	Cretaceous Mannville Formation
Top of Lower Member	-	(Birdbear Formation) - 2445 (Erosional) feet below K.B.
Drilled Depth in Feet	-	
2448 - 2454.6	-	Limestone - cryptocrystalline; fossiliferous fragmental, some whole specimens of *Eleutherokomma* sp., and *Atrypa* sp., mostly unidentifiable shell debris; poor porosity; medium olive gray; massive; slightly argillaceous.
2454.6 - 2463	-	Limestone - cryptocrystalline; fossiliferous, stropheodontid and atrypid brachiopods, bryozoa, *Tentaculites*, and scolecodonts, in some thin beds shelly material predominates giving coquinas; poor porosity; medium olive gray; some sedimentary boudinage, boudins surrounded by pale yellowish green, calcareous, waxy, flaky shale.
2463 - 2466.5	-	Limestone - microcrystalline; fair intergranular porosity; light olive gray; massive very argillaceous.

2466.5 - 2468	-	Limestone - cryptocrystalline; highly comminuted fossil debris appears to be mainly brachiopod remains, poor porosity; greenish gray; sedimentary boudinage, boudins surrounded by pale yellowish green, calcareous, earthy, flaky shale.
2468 - 2469	-	Limestone - microcrystalline; fair intergranular porosity; light olive gray; massive; very argillaceous.
2469 - 2471.5	-	Shale - medium olive gray; calcareous; earthy; massive; hard.
2471.5 -2472	-	Limestone - cryptocrystalline; highly comminuted fossil debris appears to be mainly brachiopod remains; poor porosity; greenish gray; sedimentary boudinage, boudins surrounded by pale yellowish green, calcareous, earthy, flaky, shale.
2472.5 - 2481	-	Limestone - microcrystalline; poor porosity; medium olive gray; massive; very argillaceous.

Top of Seward Member (Duperow Formation) - 2537 feet below K.B.

California Standard Fort Pitt #1-25

Lsd. 1-25-54-26W3

K.B. 2188-5

Cored Interval:	-	2135 feet - 2186 feet
Overlying beds	-	Cretaceous Mannville Formation
Top of Duperow Formation	-	2122 feet (Erosional) below K.B.
Drilled Depth in Feet	-	
2135.0-2137.4	-	Limestone - cryptocrystalline; abundant brachiopod and gastropod remains associated with globular to ovoid pellets 0.25-0.50 mm. in diameter; yellowish gray; slightly argillaceous. Sporomorphs are scattered throughout the interval. The interval is also highly fracture.
2137.4 - 2139.2	-	Limestone - cryptocrystalline; abundant brachiopod remains and some corals; light olive gray; thinly bedded with some partings of dark olive gray, calcareous shale. Some fracturing is evident in the interval.
2139.2 - 2147.5	-	Limestone - cryptocrystalline; contains ostracods and gastropods; pale yellowish brown; slightly argillaceous; some burrow-like or trail-like patterns developed on bedding surfaces. Vertical burrows or cracks filled by organic debris are also

present. Rock is highly fractured and fracture surfaces are slickensided. Trails or burrows accentuated by pyrite encrustation.

2147.5 - 2151.7	-	Limestone - cryptocrystalline; pale yellowish brown to olive gray; contains brachiopods, ostracods, gastropods, spines, some corals and sporomorphs; massive. Burrows or trails preserved by disseminated pyrite. Upper portion argillaceous becomes less argillaceous toward base of interval.
2151.7 - 2155.0	-	Limestone - cryptocrystalline; yellowish gray to pale yellowish brown; some burrows or trails in upper portion; becomes thinly laminated in lower 1.5 feet.
2155.0 - 2156.7	-	Limestone - cryptocrystalline; pale yellowish brown; massive; stromatoporoid in the upper 0.3 feet.
2156.7 - 2172.0	-	Limestone - cryptocrystalline; pale yellowish brown; contains finely comminuted fossil debris and stromatoporoids some of which are encrusting small coral colonies.

Top of the Beaverhill Lake Formation - 2244 feet below K.B.

Cored Interval	-	2310 feet - 2435 feet
2310.0 - 2318.0	-	Limestone - cryptocrystalline; yellowish gray; "pinch and swell" structures associated with the more argillaceous intervals also some incipient stylolites are present; brachiopod remains and crinoid columnals are dispersed through the rock. Within the interval there are two thin flat pebble conglomerates at 2315.7 and 2317.8. The conglomerates consist of flat, well-rounded, elongate carbonate pebbles between 1.2 and 4.0 mm. long and a high concentration of fossil detritus mainly crinoid columnals but with scattered brachiopod shell fragments and spines. The pebbles are usually emphasized by an outline of disseminated pyrite crystals.
2318.0-2319.0	-	Limestone - as above but contains three thin flat pebble conglomerates with pebbles between 2.0 mm. and 10.0 mm. Labyrinth of burrows filled with pebbles and fossil detritus in a marly matrix.
2319.0 - 2328.0	-	Limestone - cryptocrystalline; light olive gray to olive gray; with scattered brachiopod remains. Lower portion interbedded

with yellowish gray, very calcareous, compact marlstone, incipient "pinch and swell" phenomenon is common in this latter association. Several minor flat pebble conglomerates present in lower 8 feet, one well-developed conglomerate 0.2 foot thick between 2320.7 feet and 2320.9 feet.

Top of Souris River Formation - 2328 feet below K.B.

2328 - 2337.3	-	Marlstone - light olive gray; very calcareous; massive; with scattered comminuted fossil debris.
2337.3 - 2342.0	-	Limestone - microcrystalline; light olive gray to medium olive gray; "pinch and swell" structures are common; also burrows filled with marly material. Several flat pebble conglomerates thickest one is between 2338.8 feet and 2339.1 feet, others at 2340.1 and 2340.8
2342.0 - 2344.6	-	Marlstone - olive gray; very calcareous; massive to poorly bedded.
2344.6 - 2348.0	-	Limestone - cryptocrystalline; medium light gray to light olive gray; thick bedded; argillaceous; burrows are common in the lower portion - they are filled by marly material. Several flat pebble conglomerates

- are also present.

2348.0 - 2349.0 - Limestone - cryptocrystalline; contains globular to ovoid pellets 0.38 mm. to 0.76 mm. in diameter; mainly dark gray in colour. Rock appears to have been affected by early diagenetic pressures that resulted in some flowage.

2349.0 - 2351.4 - Limestone - cryptocrystalline; medium olive gray; very argillaceous; thinly bedded with interbeds of light olive gray, very calcareous, compact, marlstone.

2351.4 - 2356.0 - Marlstone - light olive gray; very calcareous; massive; with trails or burrows along bedding surfaces.

2356.0 - 2382.5 - Limestone - cryptocrystalline; contains stromatoporoids up to 5 inches in diameter and other highly comminuted fossil material of which only brachiopod shells are identifiable. Pellets ranging from 0.30 mm. to 0.76 mm. in diameter are common near the top of the interval. The rock is also pale to dark yellowish brown, poorly bedded, and slightly argillaceous.

2382.5 - 2385.0 - Limestone - cryptocrystalline; with abundant _Amphipora_ and scattered pockets of

	-	finely comminuted fossil detritus; pale yellowish brown; massive with incipient stylolites.
2385.0 - 2389.0	-	Limestone - cryptocrystalline; finely comminuted fossil debris and ovoid oolites 0.22 mm. to 0.38 mm. in diameter; pale yellowish brown; mainly massive but with intermittent thin carbonaceous shale partings.
2389.0 - 2399.1	-	Marlstone - light olive gray; very calcareous; massive; some ½ inch thick beds of olive gray, cryptocrystalline, very argillaceous limestone interbedded.
2399.1 - 2401.5	-	Limestone - cryptocrystalline; comminuted brachiopod remains; yellowish gray; some "pinch and swell" structures associated with more shaly portions. There is a 5 inch thick flat-pebble conglomerate between 2401.0 - 2401.4 with pebbles up to 2 inches long.
2401.5 - 2431.0	-	Marlstone - light olive gray; very calcareous; massive with a thin flat pebble conglomerate at 2414.3.
2431.0 - 2435.0	-	Limestone - cryptocrystalline; contains ovoid to globular pellets 0.22 mm. -3.0 mm.

in diameter; brachiopod remains are also scattered through the rock; pale yellowish brown; massive but with incipient stylolite development.

Top of the Dawson Bay Formation - 2952 feet below K.B.

Herschel-North Battleford Syndicate #1

Lsd. 8-10-49-27W3

K.B. 2086

Cored Interval:	-	2216 feet - 2260 feet
Overlying beds	-	Cretaceous Mannville Formation
Top of Duperow Formation	-	2204 (Erosional) feet below K.B.
Drilled Depth in Feet	-	
2216 - 2244	-	Limestone - cryptocrystalline; poor porosity; white to very pale orange; massive with finely disseminated pyrite; dolomitic.
2244 - 2252	-	Limestone - microcrystalline; scattered comminuted fossil remains; carbonaceous flecks may be scolecodonts; poor porosity; light olive gray; massive.
2252 - 2260	-	Limestone - cryptocrystalline; fossiliferous fragmental with crinoid ossicles, bryozoan and algal remains; poor porosity; pale yellowish brown; massive.
Cored Interval:	-	2323 feet - 2384 feet
2323 - 2332	-	Limestone - microcrystalline; fair to good intergranular porosity; light olive gray; massive; argillaceous.
2332 - 2338	-	Limestone - cryptocrystalline; fair inter-

	-	granular porosity; light olive gray; poorly bedded; very argillaceous.
2338 - 2352	-	Limestone - cryptocrystalline; fossiliferous fragmental; fossil content increases downward, remains mostly unidentifiable except for scattered atrypid brachiopods, very finely disseminated pyrite encrusting fossil fragments; poor porosity; light olive gray; massive with some incipient stylolites; argillaceous.
2352 - 2384	-	Limestone - cryptocrystalline; poor porosity; light olive gray; massive; irregularly shaped patches of finely disseminated pyrite dispersed through rock; argillaceous.

Top of Souris River Formation - 2412 feet below K.B.

APPENDIX F

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All Photographs are Natural Size unless otherwise stated.

PLATE 1

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Figure 1 - Elstow Member - Argillaceous fossiliferous limestone containing coarsely to finely comminuted brachiopod and ostracod remains and calcispheres in a matrix of highly argillaceous micritic limestone. California Standard Laird 16-16 well, Lsd. 16-16-43-4W3, - 1965 feet.

Figure 2 - Upper Member - Birdbear Formation - Laminated strata composed of light coloured laminae of micritic limestone and dark layers of carbonaceous material intermixed with micrite. Tidewater Morse Crown No. 1 well, Lsd. 16-25-16-8W3, - 4762.7 - 4763.0 feet.

Figure 3 - Upper Member - Birdbear Formation - Laminated strata similar to figure 2. Note the anhydrite crystals in some of the light coloured layers. Also note the algal nodule in the lower left hand corner of the specimen. Tidewater Morse Crown No. 1 well, Lsd. 16-25-16-8W3, - 4762.3 - 4762.7 feet.

Plate I

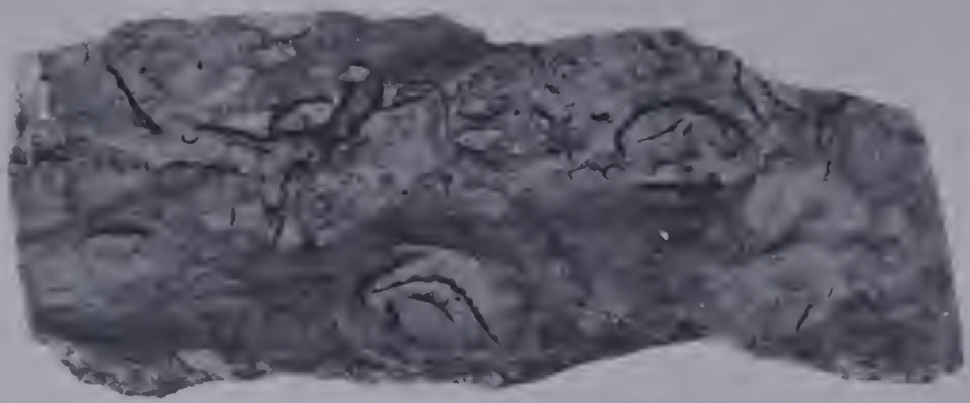

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PLATE 2

Figure 1 - Upper Member - Birdbear Formation - Laminated strata composed of alternating laminae of light coloured micrite and dark coloured mixtures of micrite and carbonaceous material. Light coloured laminae show some disruption probably due to "pinch and swell" phenomenon. The laminations are interrupted by a bed of carbonaceous micrite. Tidewater Morse Crown No. 1, - Lsd. 16-25-16-8W3, - 4789.9 feet.

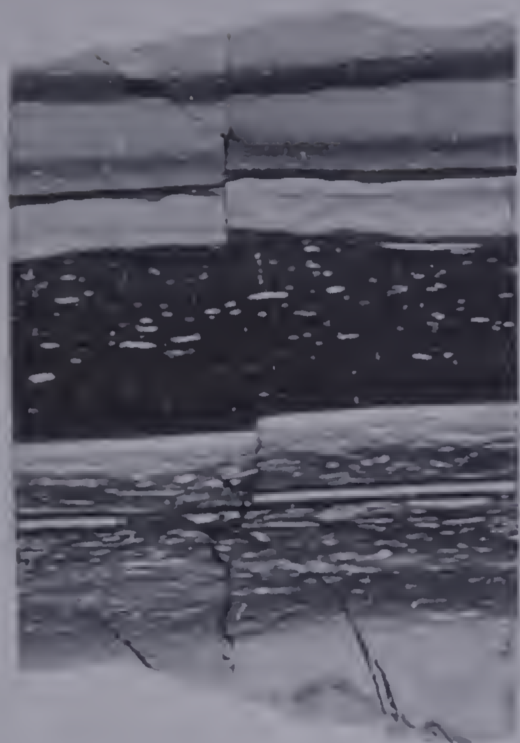
Figure 2 - Wymark Member - Micro-thrust faulting in laminated strata. The apparent throw on the thrust is in the order of 20 mm. to the right hand side of the photograph. The rock consists of light coloured micrite and dark coloured micrite and intermixed carbonaceous material. Tidewater Wymark Crown No. 1, - Lsd. 3-10-14-14W3, - 5624.5 feet.

Figure 3 - Wymark Member - Recumbent Fold in laminated strata. The rock consists of light coloured micrite and a dark coloured intermixture of micrite and carbonaceous material. Tidewater Wymark Crown No. 1, Lsd. 3-10-14-14W3, - 5692.6 feet.

Figure 4 - Wymark Member - Box fold in laminated strata. The rock consists of pelletoidal micrite and partings

- of carbonaceous material with intermixed dolomite rhombs. Tidewater Wymark Crown No. 1, - Lsd. 3-10-14-14W3, - 5675.0 feet.

Plate 2



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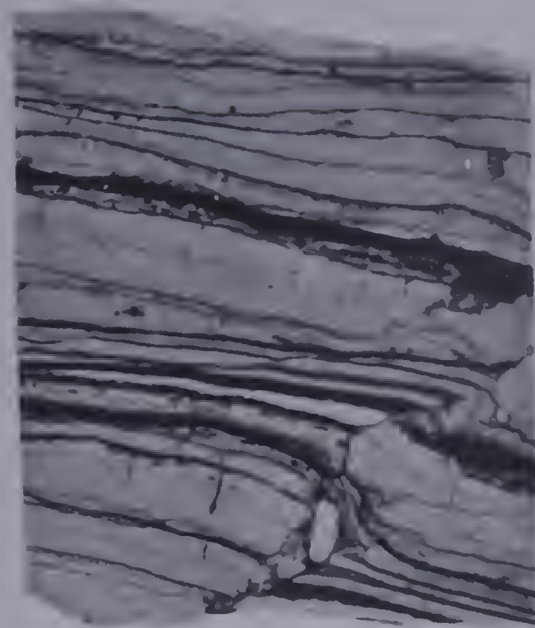

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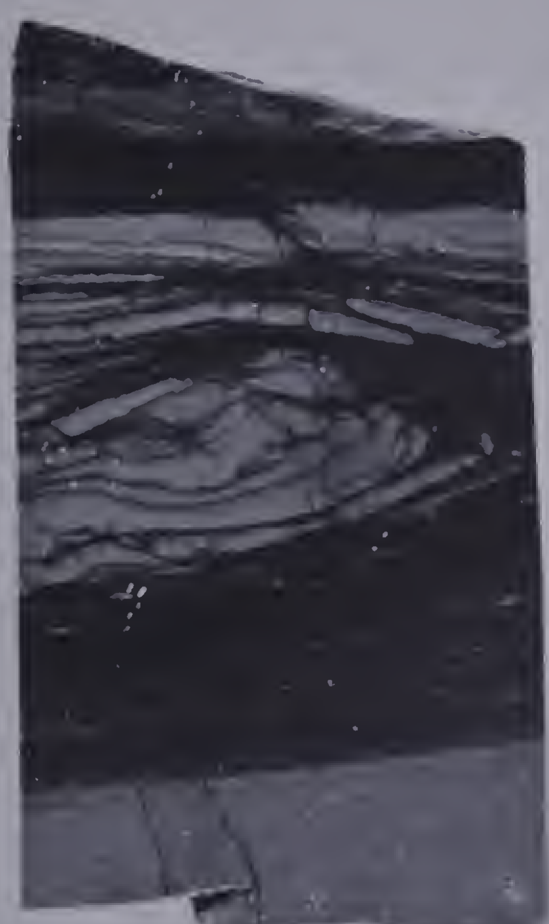

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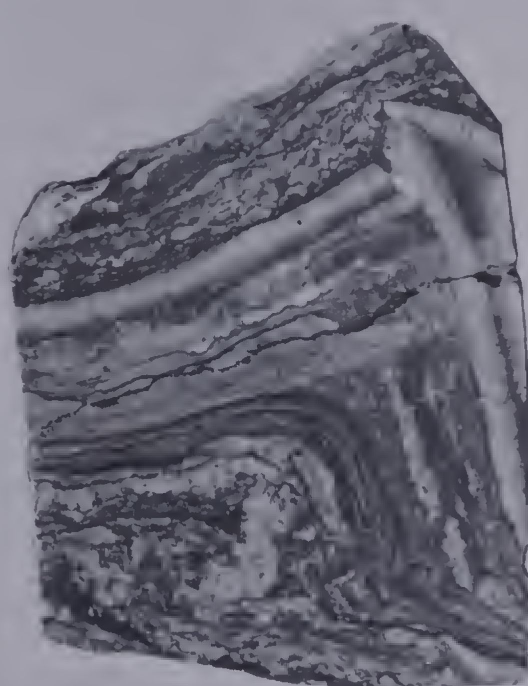

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PLATE 3

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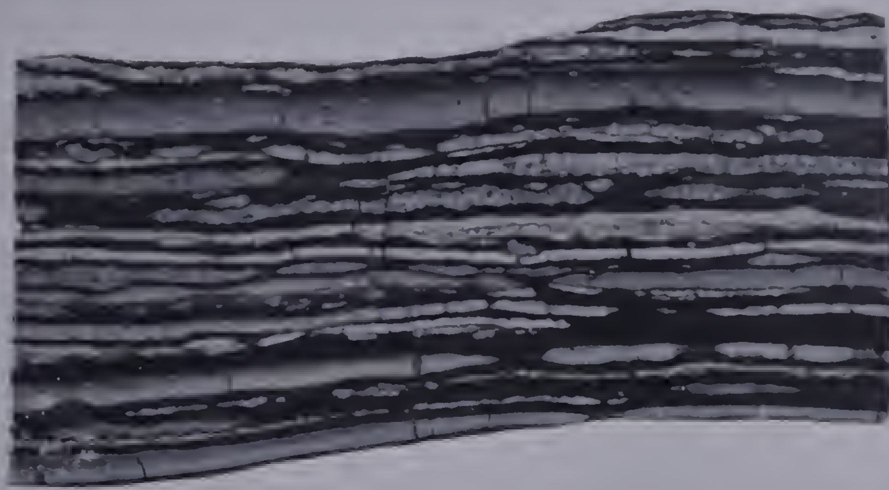
Figure 1 - Lower Member - Birdbear Formation - Sedimentary boudinage structures developed in laminated strata. Lighter coloured layers are composed of micritic limestone, pellets and other intraclasts. The dark laminae consist of carbonaceous material intermixed with micrite. Note the "necking-down" of some of the light coloured laminae and the tension fractures that were also formed in these laminae. Tidewater Birsay Crown No.1 well, - Lsd. 13-4-25-8W3, - 3854 feet.

Figure 2 - Elstow Member - Sedimentary boudinage developed in an alternating sequence of non-argillaceous or slightly argillaceous carbonate and calcareous shale or marlstone. The limestone is micrite with scattered brachiopod and ostracod remains. The carbonate layers have been drawn out and ruptured giving the rock a nodular appearance. Noted the clusters of disseminated pyrite replacing portions of the rock on the right hand side of the specimen. California Standard Laird 16-16 well, - Lsd. 16-16-43-4W3, - 1958.5 feet.

Plate 3



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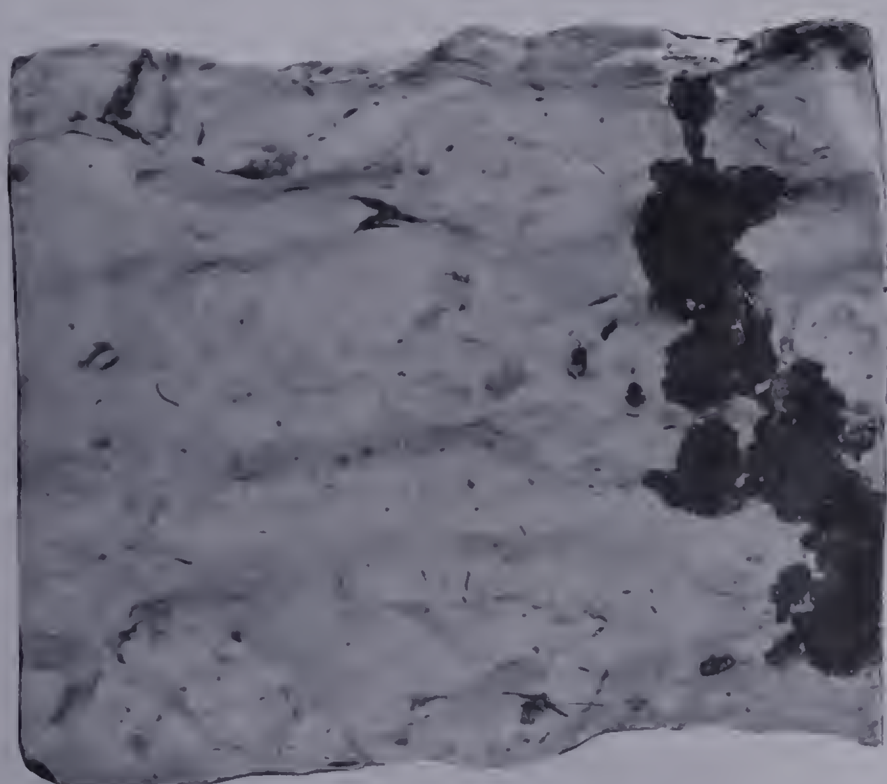

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PLATE 4

Figure 1 - Wymark Member - Sedimentary boudinage in fossiliferous micrite. Lighter portions of specimen contain brachiopods, crinoid columnals and some ostracods. The darker portions consists of carbonaceous material intermixed with micritic limestone and dolomite rhombs. Tidewater Eastend Crown No. 1, - Lsd. 15-11-6-20W3, - 6029.2 - 6029.6 feet.

Figure 2 - Wymark Member - Sedimentary boudinage similar to that described and illustrated in Figure 1. Tidewater Eastend Crown No. 1, - Lsd. 15-11-6-20W3, - 6051.9 - 6052.2 feet.

Plate 4

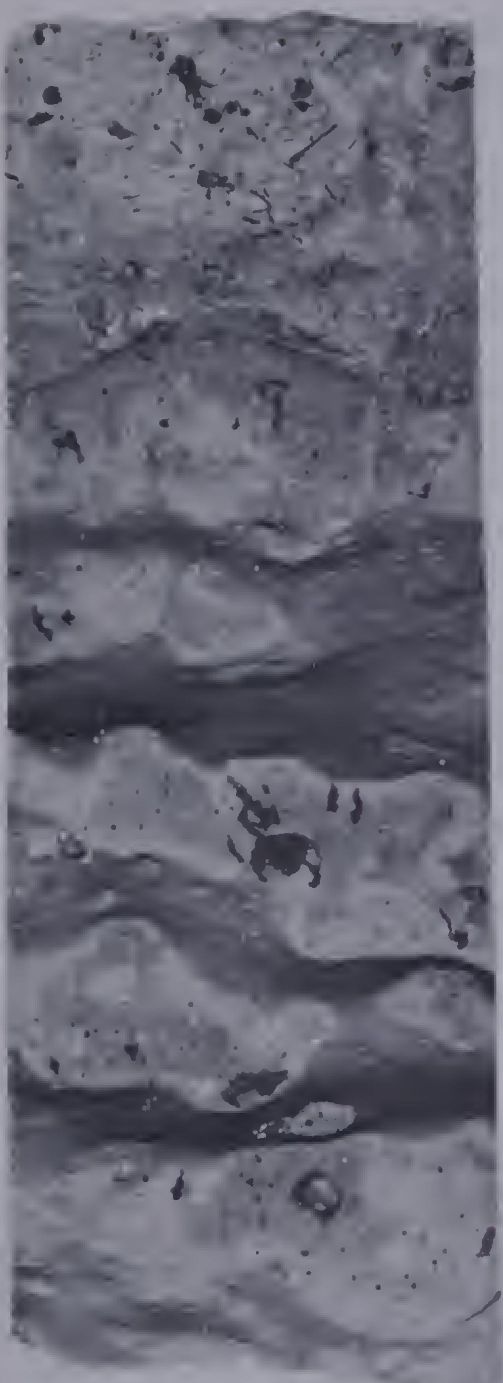

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PLATE 5

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Figure 1 - Wymark Member - Compaction structures developed in a manner similar to sedimentary boudinage but due to the thickness of the limestone layers few "pinch and swell" structures were produced. The partings consist of carbonaceous material intermixed with micrite and the limestone layers are micrite with little or no fossil material. Tidewater Wymark Crown No. 1 well, - Lsd. 3-10-14-14W3, - 5613.6 feet.

Figure 2 - Wymark Member - Compaction structures similar to those of Figure 1. Tidewater Wymark Crown No. 1 well, - Lsd. 3-10-14-14W3, - 5610.3 feet.

Plate 5

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PLATE 6

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Figure 1 - Seward Member - Indistinct stratification in highly argillaceous carbonate rock. The rock consists of micrite with ostracod valves and crinoid columnals. Scattered angular quartz grains are also present. Tidewater Parkbeg Crown No. 1 well, - Lsd. 10-32-18-3W3, - 4715.7 feet - 4716.2 feet.

Figure 2 - Seward Member - Indistinct stratification in highly calcareous argillaceous rock. The rock consists of a slightly dolomitized marlstone with scattered angular quartz grains. Tidewater Parkbeg Crown No. 1, well, - Lsd. 10-32-18-3W3, - 4753.2 feet - 4753.5 feet.

Plate 6

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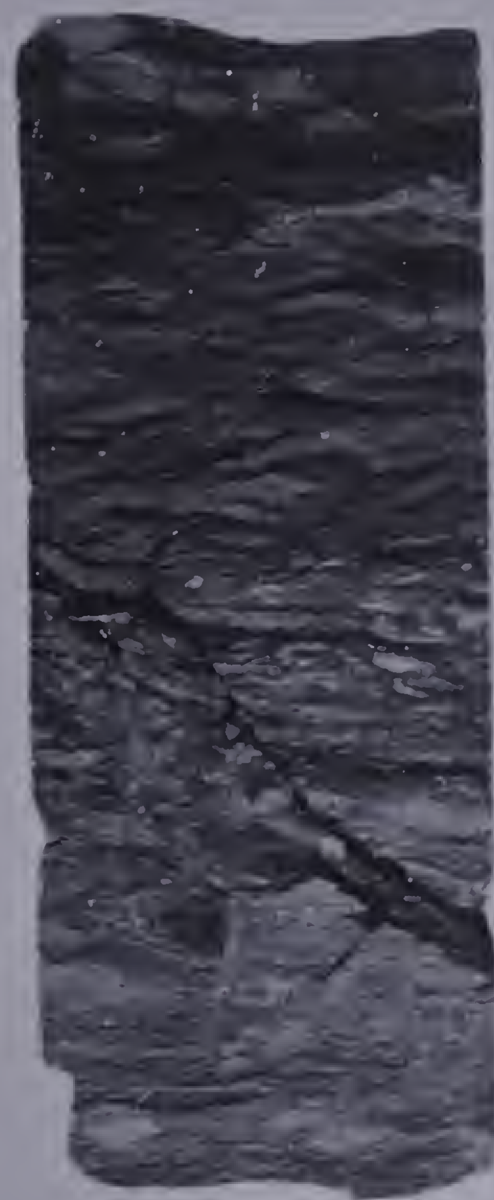

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PLATE 7

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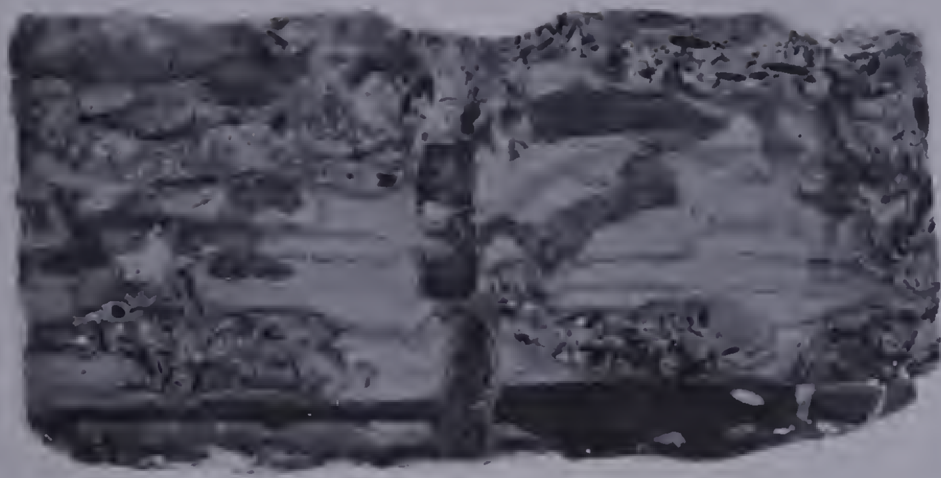
Figure 1 - Argillaceous facies of Saskatoon Member - Flat pebbles in burrows. Pebbles are composed of highly argillaceous carbonate rock with extremely finely disseminated pyrite. Included with the pebbles are fragments of organic material. California Standard Fort Pitt 1-25 well, - Lsd. 1-25-54-26W3, - 2318 feet.

Figure 2 - Argillaceous facies of Saskatoon Member - Flat pebble bed. Pebbles are composed of highly argillaceous carbonate rock in a marlstone matrix. There is also a strong concentration of fossil fragments associated with the pebbles. California Standard Fort Pitt 1-25 well, - Lsd. 1-25-54-26W3, - 2344.5 feet.

Figure 3 - Upper Member Birdbear Formation - Intraformational breccia. Fragments composed of subhedral to anhedral dolomite in a matrix of euhedral dolomite and anhydrite. Imperial Tidewater Climax 6-10-3-18 well, - Lsd. 6-10-3-18W3, - 5698.6 feet.

Plate 7



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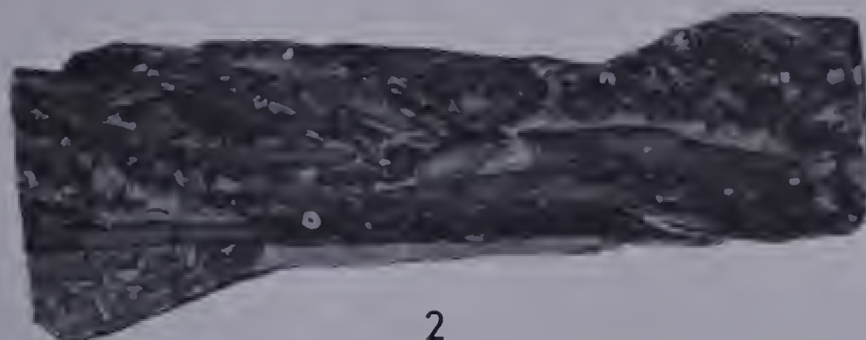

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PLATE 8

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Figure 1 - Wymark Member - Incipient stylolite development in a micrite with some pellets. The upper portion is particularily pelletoid but many of the pellets are obliterated by the solution phenomenon which produced the microstylolites. Tidewater Wymark Crown No. 1 well, - Lsd. 3-10-14-14W3, - 5414.8 feet - 5415.2 feet.

Figure 2 - Wymark Member - Incipient stylolite development in a fossiliferous partially dolomitized micrite. Fossils include brachiopods and ostracod fragments. Tidewater Morse Crown No. 1 well, - Lsd. 16-25-16-8W3, - 5047.8 feet - 5048.1 feet.

Plate 8

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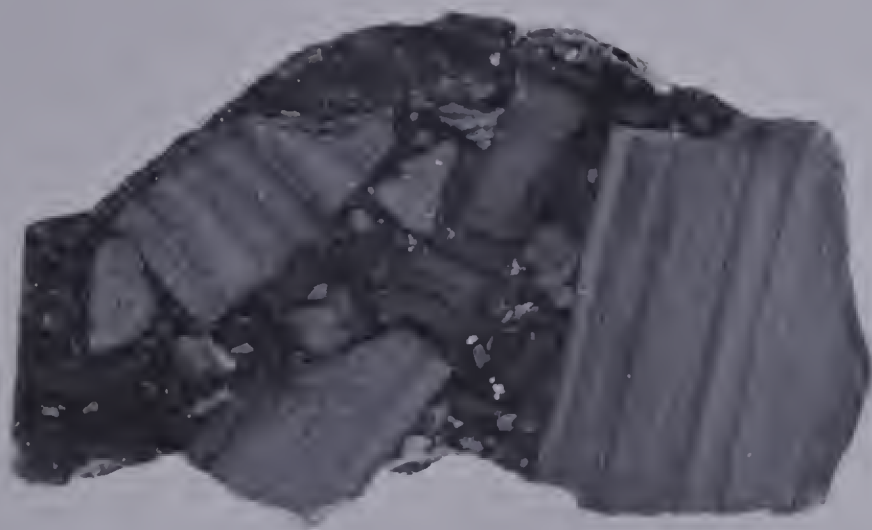
PLATE 9

Figure 1 - Wymark Member - Solution collapse breccia probably the lateral equivalent of the Dinsmore Evaporite of the Wymark Member. The fragments consist of a variety of carbonate rock types including laminated micrite and pelletoid micrite. The fragments range in size from those which are visible in the illustration to ones which are difficult to distinguish from the matrix. The matrix consists of very fine-grained anhedral calcite; subangular and spherulitic quartz is dispersed through it. United States Borax and Chemical Elstow 5-22A well, Lsd. 5-22-34-1W3, - 2245.0 feet.

Figure 2 - Jefferson Formation - Solution collapse breccia probably the lateral equivalent of anhydrites in the subsurface. Fragments and matrix both consist of limestone with only scattered dolomite rhombs. In most instance the fragments appear to be aggregations of other fragments. The matrix includes rock flour and some sparry calcite. The latter probably was deposited in original void spaces in the breccia. Newland Creek Surface Section, South Little Belt Mountains, Montana, S.W. Sec. 16, T. 10N, R 6E, 160' above the base of the section.

Plate 9



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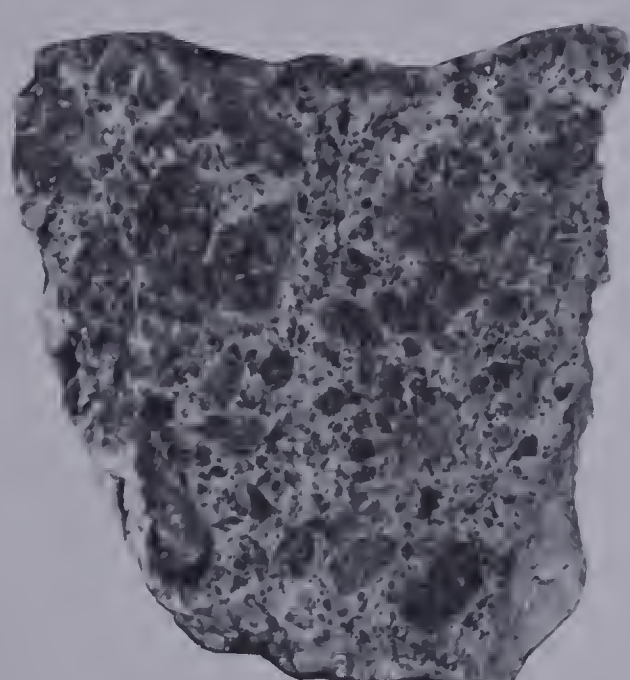

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PLATE 10

Figure 1 - Upper Member - Birdbear Formation - Mottled limestone. The specimen is a partially dolomitized micritic limestone. The lighter coloured areas consist of dolomitized micrite or euhedral and subhedral dolomite crystals and the darker coloured portions are composed of sparry calcite. Some of the sparry calcite is in the form of fibrous appearing radially orientated crystals. Tidewater Morse Crown No. 1 well, Lsd. 16-25-16-8W3, - 4777.0 feet -4777.4 feet.

Figure 2 - Seward Member - Secondary Anhydrite. This specimen illustrates both metasomatic and void-filling anhydrite. The dark crystals are metasomatic replacements of a micritic limestone. They are dusky yellowish brown in colour and have an anhedral to subhedral crystal habit.

The lighter coloured, somewhat arcuate area in the central and lower portion of the specimen was a void which has been filled by clear crystalline anhydrite. Tidewater Parkbeg Crown No. 1 well, -
Lsd. 10-32-18-3W3, - 4793.0 feet - 4793.3 feet.

Plate 10

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PLATE 11

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Figure 1	-	Wymark Member - Stromatolitic carbonate. The lighter laminated portions are dolomitized micrite with scattered algal tubes. The darker parts particularly at the top and middle of the specimen consists of algal tubes filled with sparry calcite. Tidewater Eastend Crown No. 1 well, - Lsd. 15-11-6-20W3, - 6128.2 feet - 6128.5 feet.
Figure 2	-	Wymark Member - Crossbedded pelletoid limestone with concentric singular algal growths about one-third of the vertical distance from the base. The pellets are cemented by sparry calcite which has been partially dolomitized. Tidewater East-end Crown No. 1 well, - Lsd. 15-11-6-20W3, - 6093.7 feet - 6093.9 feet.

Plate II

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PLATE 12

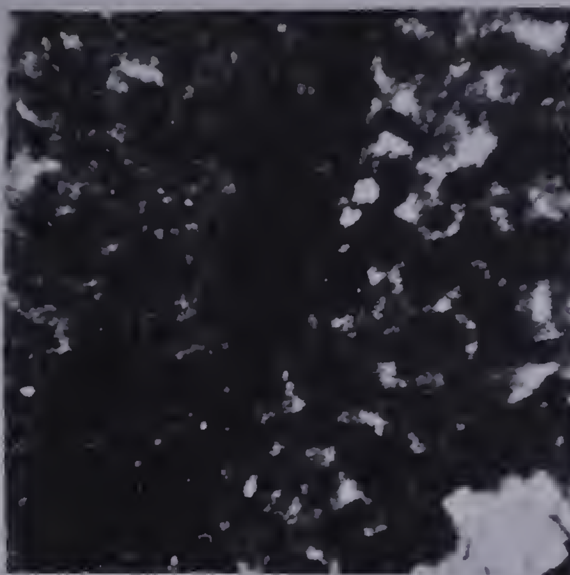
Figure 1 - Wymark Member - Photomicrograph illustrating the manner by which pellets are obliterated within the zone of microstylolite development. Crossed nicols, 44X. Tidewater Wymark Crown No. 1 well, - Lsd. 3-10-14-14W3, - 5414.8 feet.

Figure 2 - Wymark Member - Photomicrograph illustrating a concentration of dolomite rhombs in a microstylolitic zone. The narrow dark streak in the dolomitic portion is some of the carbonaceous material associated with microstylolites. Plain light, 44X. Tidewater Eastend Crown No. 1 well, - Lsd. 15-11-6-20W3, - 6106.4 feet.

Figure 3 - Seward Member - Photomicrograph illustrating radially fibrous calcite replacing pellets in a micritic limestone. Note how one irregularly-shaped pellet is almost completely replaced and replacement had only commencing on other pellets. Crossed nicols, 47X. Saskoil Leader No. 1 well, - Lsd. 9-15-20-25W3, - 3946.2 feet.

Figure 4 - Upper Member - Birdbear Formation. Photomicrograph illustrating fibrous calcite grain enlargment and partial void-filling of an ostracod carapace. Note how some of the other carapace have

Plate 12



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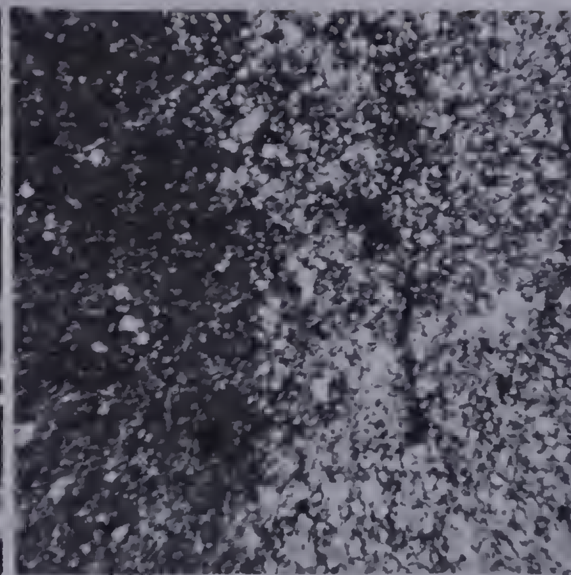

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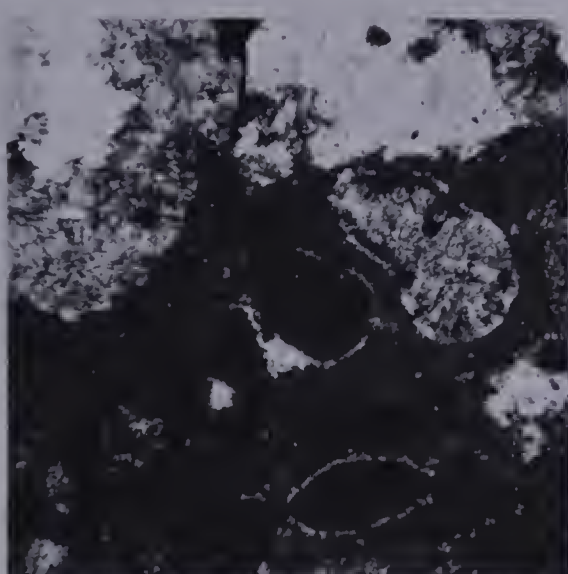

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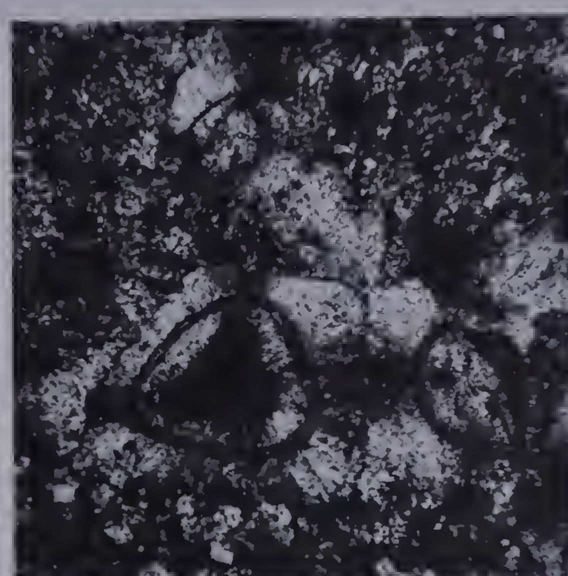

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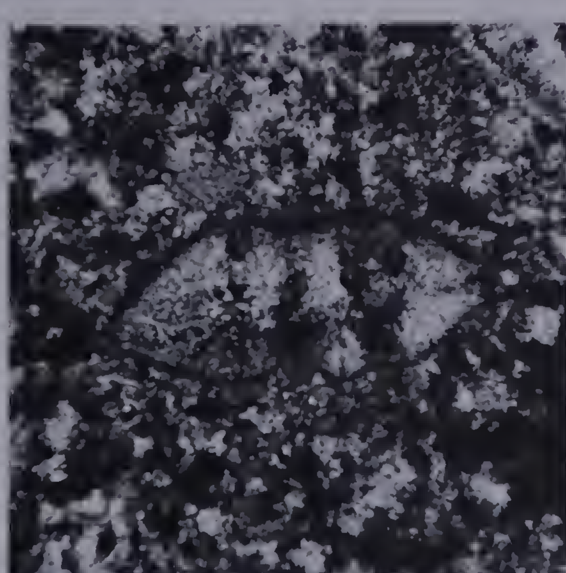

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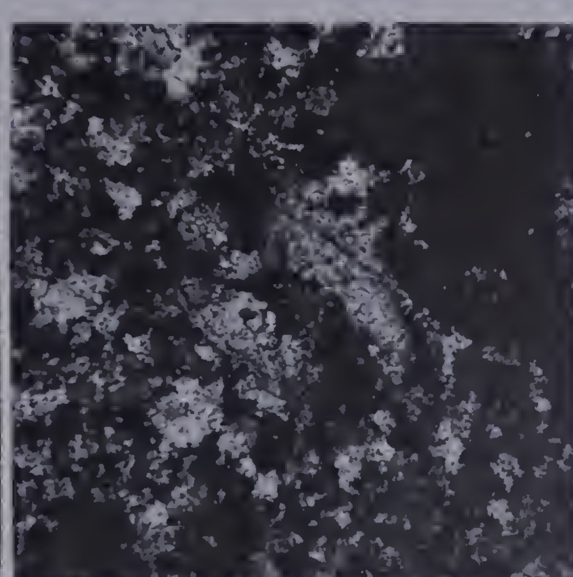

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PLATE 13

Figure 1 - Upper Member - Birdbear Formation. Photomicrograph illustrating fibrous calcite when fossil is completely obliterated. Crossed nicols, 47X. Tidewater Morse Crown No. 1 well, - Lsd. 16-25-16-8W3, - 4777.0 feet.

Figure 2 - Upper Member - Birdbear Formation. This photomicrograph illustrates spherulitic chalcedony in an anhydrite matrix. Note the undulatory extinction of the chalcedony. Crossed nicols, 150X. Tidewater Morse Crown No. 1 well, - Lsd. 16-25-16-8W3, - 4763.5 feet.

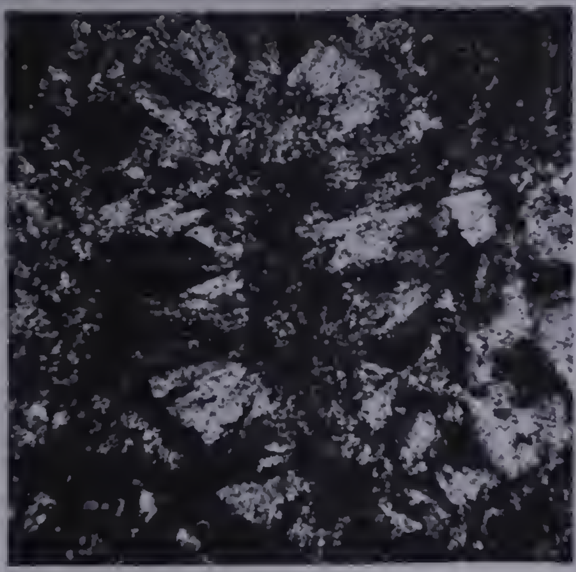
Figure 3 - As in figure 2. Plain light, 150X.

Figure 4 - Wymark Member - This photomicrograph illustrates coalesced spherulitic chalcedony. Crossed nicols, 140X. Tidewater Vanguard Crown No. 1 well, - Lsd. 14-30-12-9W3, - 5803.5 feet.

Figure 5 - As in figure 4. Plain light, 150X.

Figure 6 - Upper Member - Birdbear Formation. Photomicrograph illustrating the arched blade-type of chalcedony in an anhydrite matrix. Note the undulatory extinction which imparts a fibrous appearance to the chalcedony. Crossed nicols, 150X, Tidewater Morse Crown No. 1, well, - Lsd. 16-25-16-8W3, - 4763.5 feet.

Plate 13



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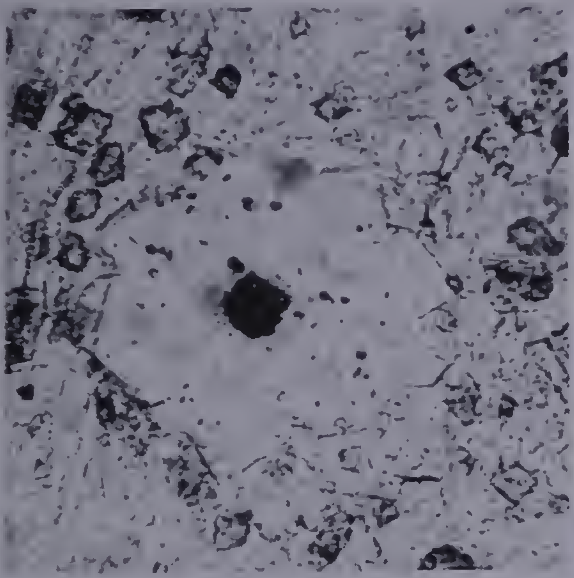

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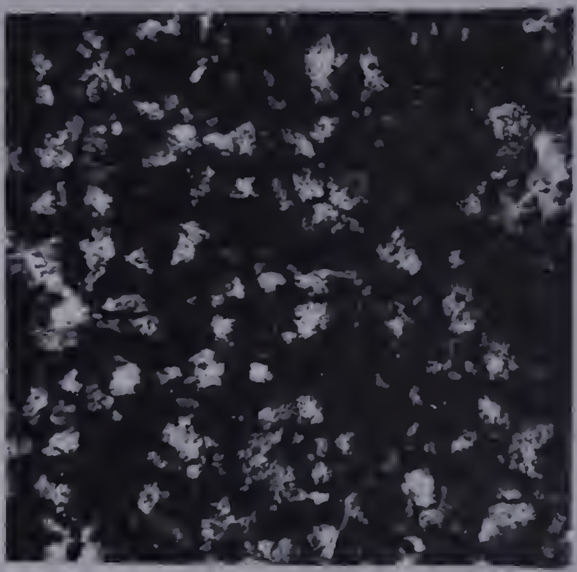

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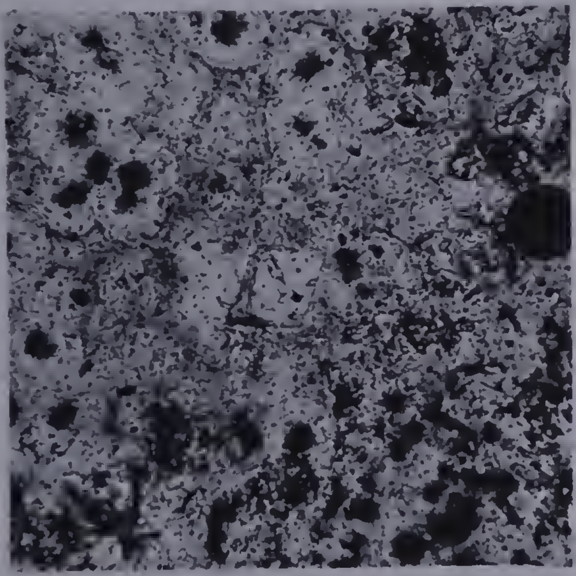

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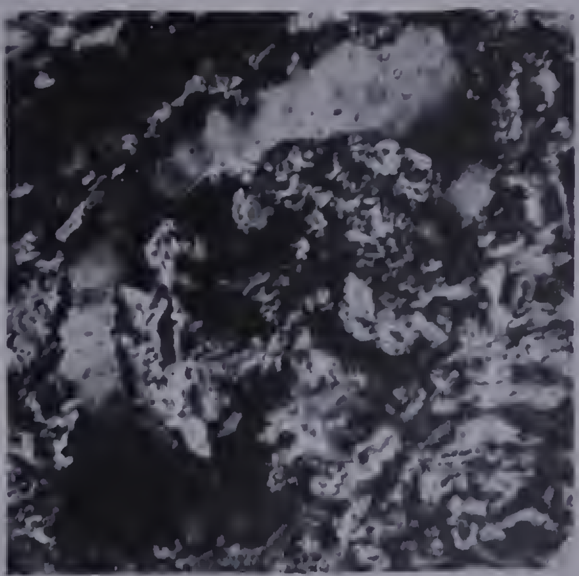

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PLATE 14

Figure 1 - Upper Member - Birdbear Formation. Photomicrograph illustrating arched blade-type chalcedony. Crossed nicols, 47X. Tidewater Morse Crown No. 1 well, -
Lsd. 16-25-16-8-W3, - 4763.5 feet.

Figure 2 - Upper Member - Birdbear Formation. Photomicrograph illustrating straight blade-type chalcedony. Crossed nicols, 150X. Tidewater Morse Crown No. 1 well, -
Lsd. 16-25-16-8-W3, - 4763.5 feet.

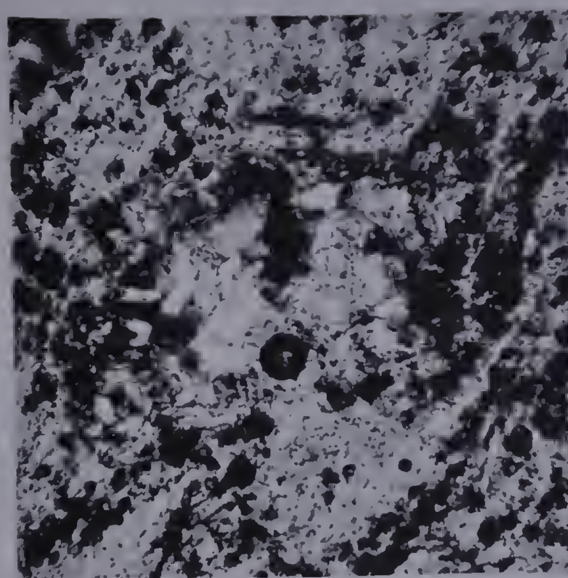
Figure 3 - Upper Member - Birdbear Formation. This photomicrograph illustrates the ovate type of chalcedony development. The form illustrated is enclosing grains of anhydrite. Crossed nicols, 48X. Tidewater Morse Crown No. 1 well, -
Lsd. 16-25-16-8W3, - 4763.5 feet.

Figure 4 - Upper Member - Birdbear Formation. Photomicrograph illustrating ovate type of chalcedony enclosing a crystal of dolomite. Crossed nicols, 53X. Tidewater Morse Crown No. 1 well,
Lsd. 16-25-16-8W3, - 4763.5 feet.

Figure 5 - As in figure 4, Plain light, 53X.

Figure 6 - Upper Member - Birdbear Formation. Photomicrograph illustrating granular clusters of silica in an anhydrite matrix. Crossed nicols, 170X. Tidewater Morse Crown No. 1 well, - Lsd. 16-25-16-8W3, - 4763.5 feet.

Plate 14



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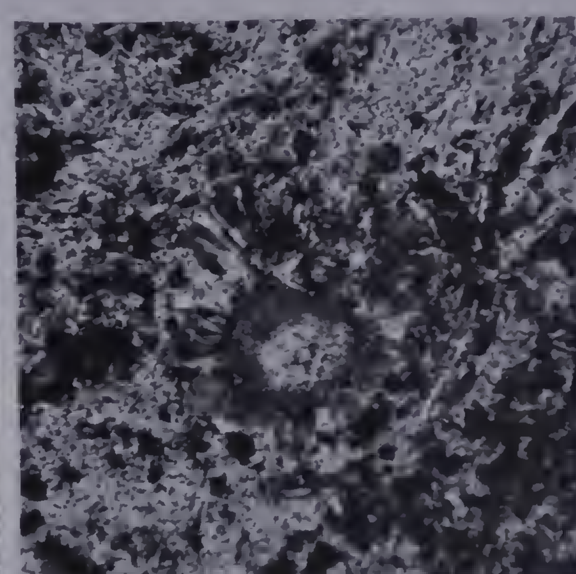

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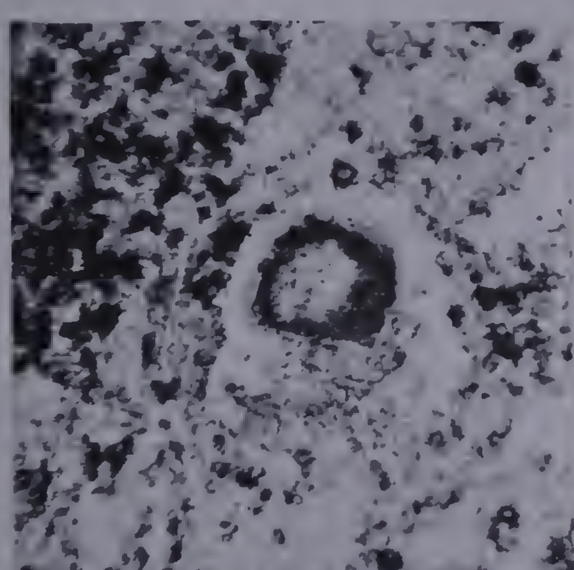

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PLATE 15

Figure 1 - Upper Member - Birdbear Formation. Photomicrograph illustrating microcrystalline quartz with scattered dolomite rhombs. Crossed nicols, 150X. Imperial Tidewater Climax 6-10-3-18 well, - Lsd. 6-10-3-18W3, - 5709.3 feet.

Figure 2 - Wymark Member - This photomicrograph illustrates microcrystalline quartz replacing carbonate aggregates and forming overgrowths on the replaced carbonate. The former carbonate material appears as relicts in the quartz. Plain light, 48X. Tidewater Wymark Crown No. 1 well, - Lsd. 3-10-14-14W3, - 5663.8 feet.

Figure 3 - Seward Member - Photomicrograph illustrating an association of microcrystalline and euhedral quartz. The small felted appearing patches on the right hand side of the figure consists of anhydrite. Crossed nicols, 45X. Tidewater Parkbeg Crown No. 1 well, - Lsd. 10-32-18-3W3, - 4760.5 feet.

Figure 4 - Wymark Member - Photomicrograph illustrating quartz replacing a dolomite rhomb. Note some unreplaced dolomite along the left hand side and in the lower left hand corner of the pseudomorph. Plain light, 120X. Tidewater Vanguard Crown No.1

- well, -

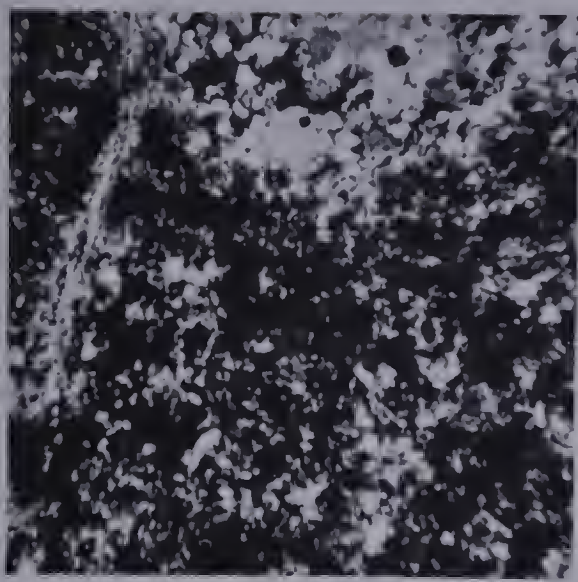
Lsd. 14-30-12-9W3, - 5803.5 feet.

Figure 5 - Seward Member - Photomicrograph illustrating euhedral quartz which appears to be partially replaced by anhydrite, particularly along the upper and right sides of the crystal. Crossed nicols, 165X. Tidewater Parkbeg Crown No. 1 well, -

Lsd. 10-32-18-3W3, - 4760.5 feet.

Figure 6 - As in figure 5. Plain light, 165X.

Plate 15



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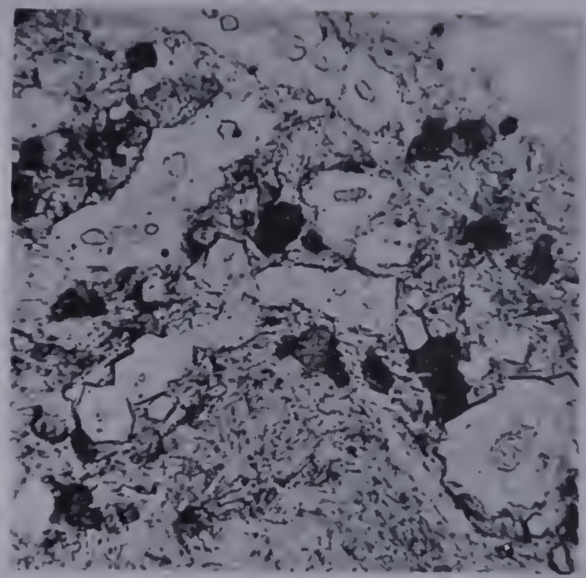

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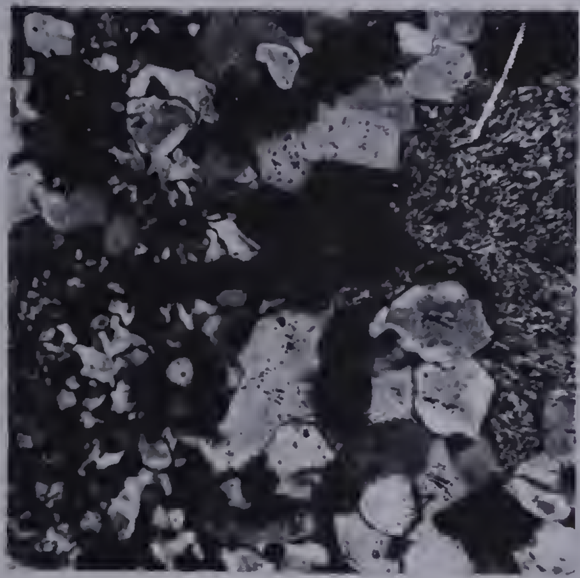

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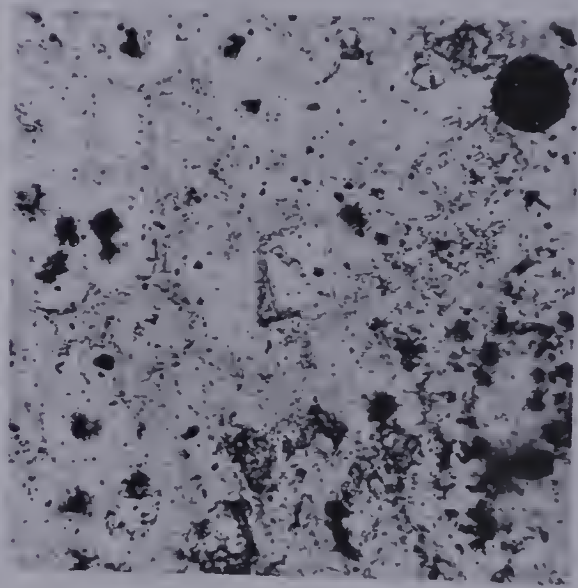

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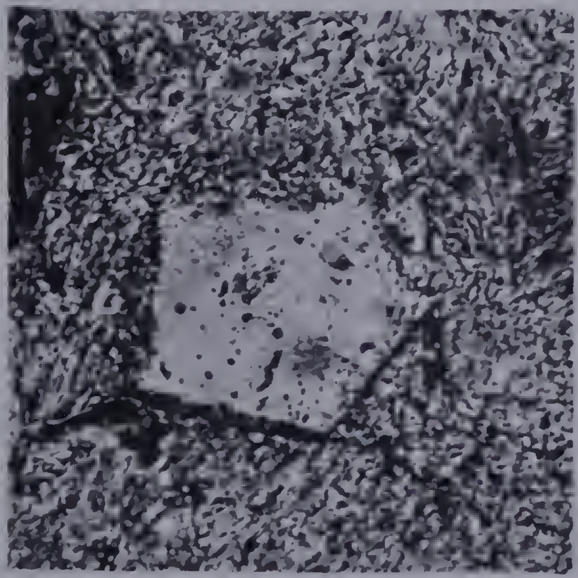

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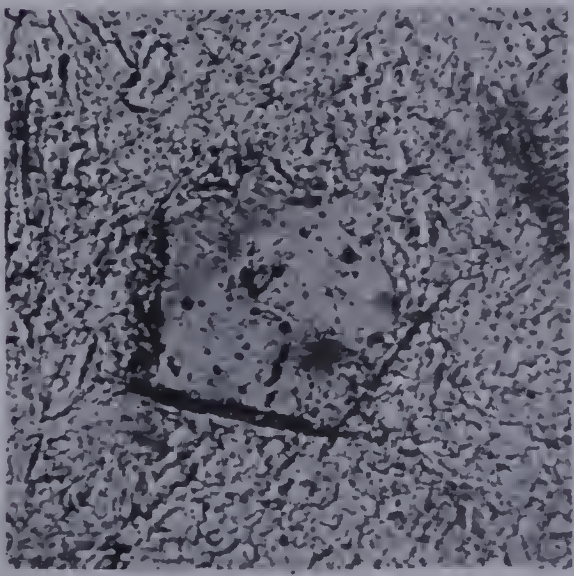

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PLATE 16

Figure 1 - Seward Member - Photomicrograph illustrating euhedral quartz some of which appears to be partially replaced by anhydrite. Crossed nicols, 48X. Tidewater Parkbeg Crown No. 1 well, - Lsd. 10-32-18-3W3, - 4760.5 feet.

Figure 2 - As in figure 1. Plain light, 48X.

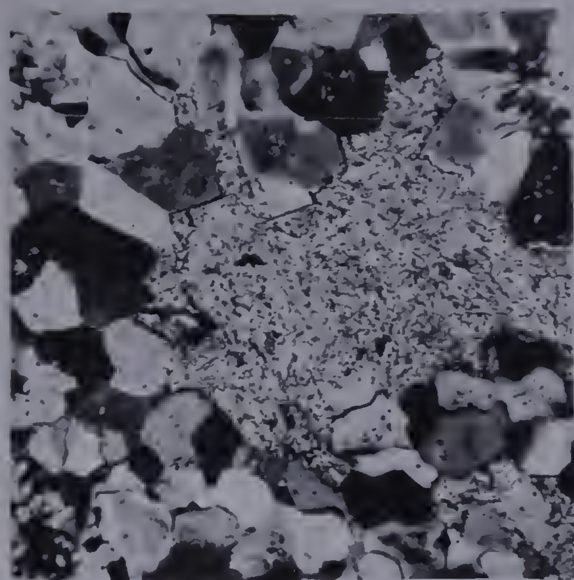
Figure 3 - Seward Member - Photomicrograph illustrating metasomatic anhydrite replacing a fossiliferous micrite. The micrite contains calcispheres and ostracod valves. Crossed nicols, 45X. Tidewater Parkbeg Crown No. 1 well, - Lsd. 10-32-18-3W3, - 4793.0 feet.

Figure 4 - Upper Member - Birdbear Formation. This photomicrograph illustrates a large euhedral crystal of anhydrite and several smaller euhedral to subhedral crystals filling the void spaces in a rhombic dolomite. Crossed nicols, 45X. Tidewater Parkbeg Crown No. 1 well, - Lsd. 10-32-18-3W3, - 4574.0 feet.

Figure 5 - Upper Member - Birdbear Formation. Photomicrograph illustrating a spherite replaced by radially-orientated bacillar anhydrite. The spherite may have originally been composed of radially

	-	orientated calcite crystals. Crossed nicols, 45X. Tidewater Parkbeg Crown No. 1 well, - Lsd. 16-25-16-8W3, - 4773.5 feet.
Figure 6	-	Upper Member - Birdbear Formation. Photomicrograph illustrating metasomitic anhydrite that appears to be replacing the micritic envelope of a recrystallized spherite. Crossed nicols, 47X. Tidewater Glen Bain Crown No. 1, - Lsd. 8-22-10-8W3, - 5407.3 feet.

Plate 16



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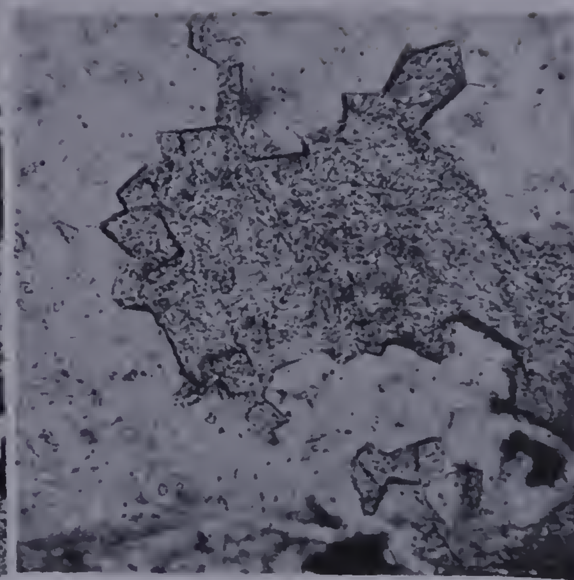

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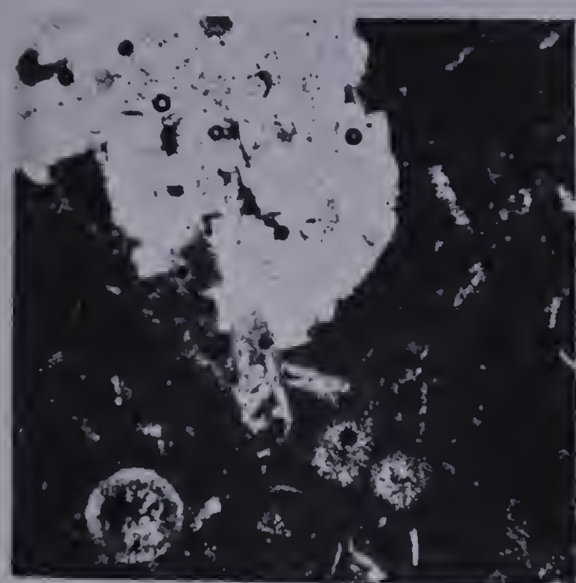

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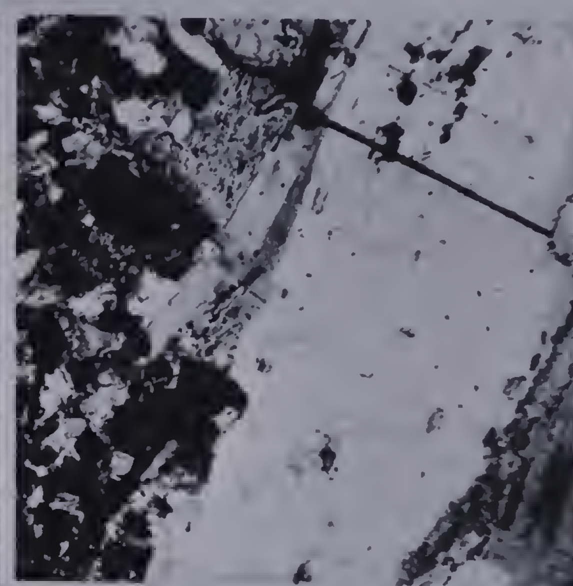

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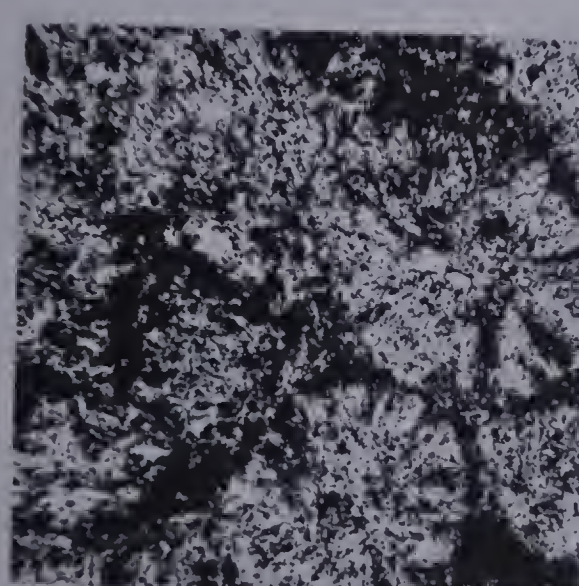

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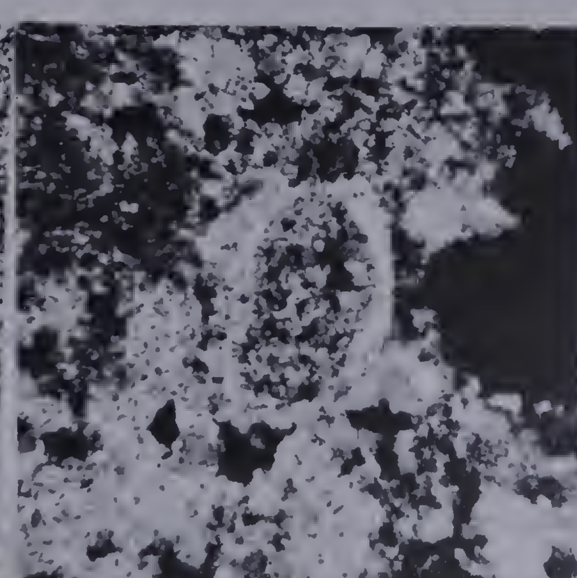

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PLATE 17

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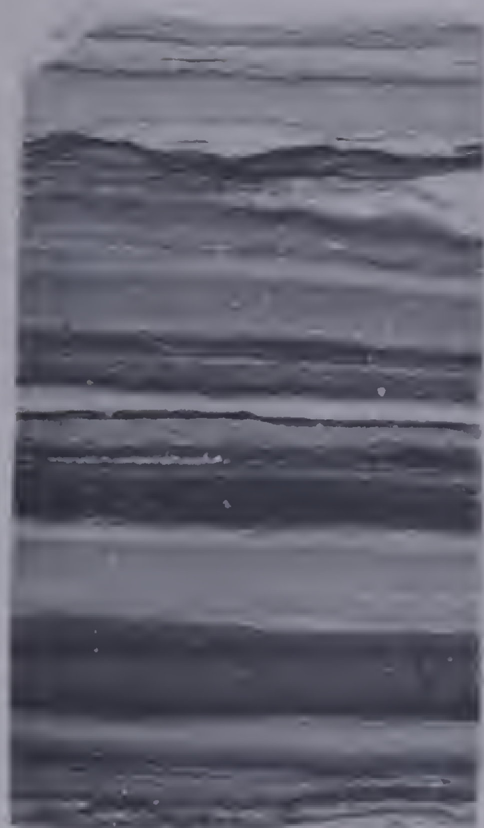
Figure 1 - Upper Member - Birdbear Formation. Highly argillaceous bedded anhydrite. The rock is composed of granular and some felty anhydrite intermixed with argillaceous and calcareous materials. Tidewater Imperial Forgan No. 1 well, -
Lsd. 4-16-27-13W3, - 2840.5 feet.

Figure 2 - Wymark Member - Bedded anhydrite grading upward into highly argillaceous anhydrite and shale. Tidewater Morse Crown No. 1 well, -
Lsd. 16-25-16-8W3, - 5053.9 feet.

Figure 3 - Wymark Member - Replacement anhydrite (gray in colour) composed of felty and granular anhydrite. The dolomite patches (white) consists of euhedral to subhedral dolomite grains with felty and granular anhydrite in the interstices. Royalite General American Coleville Water Disposal well No. 1, -
Lsd. 15-31-31-23W3, - 3715.0 feet.

Plate 17



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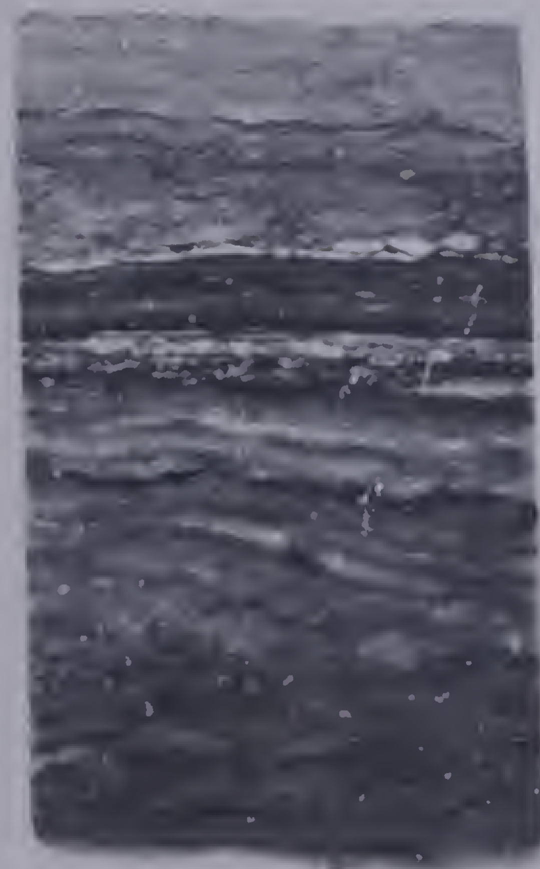

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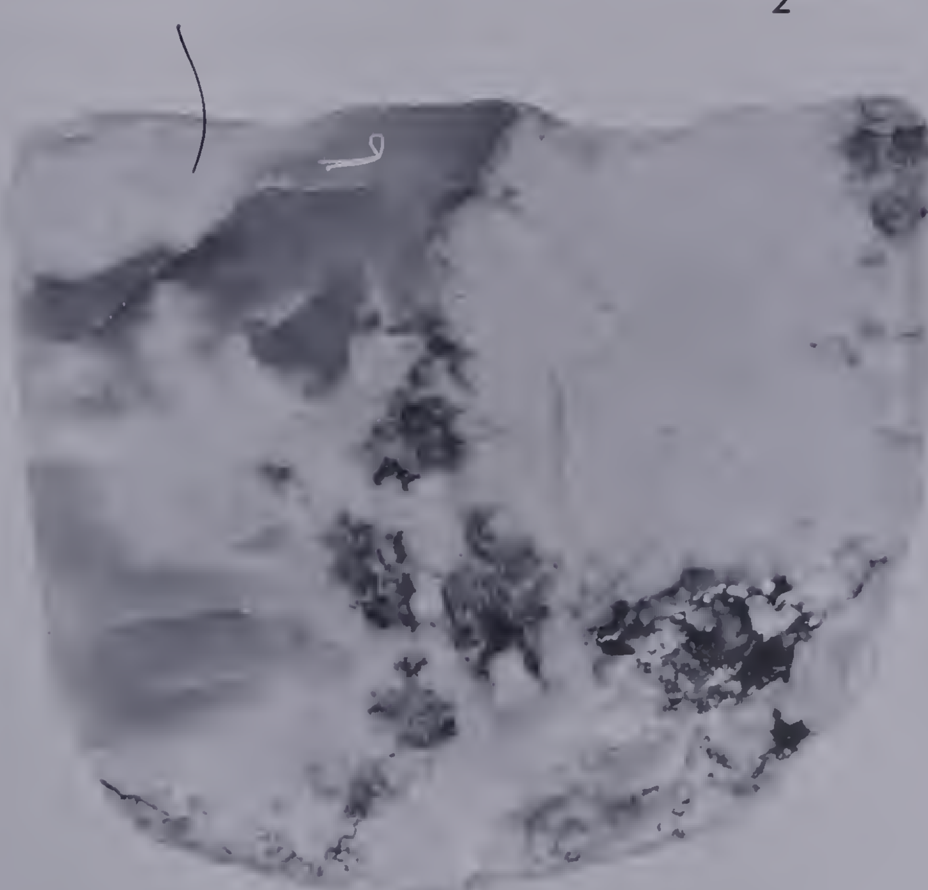

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PLATE 18

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Figure 1 - Upper Member Birdbear Formation - Bedded anhydrite with crenulated layers of argillaceous and anhydritic carbonate. The fabric of the rock includes felty and bacillar anhydrite and extremely fine-grained anhedral dolomite. The small subcircular white areas are composed of chalcedonic quartz most often in the form of spherulites. (see Plate 13, Figures 1 and 2). Tidewater Morse Crown No. 1 well, - Lsd. 16-25-16-8W3, - 4763.5 feet.

Figure 2 - Wymark Member - Nodular or macrocellular anhydrite having a fabric of felty anhydrite with patches of bacillar anhydrite. Tidewater Wymark Crown No. 1 well, - Lsd. 3-10-14-14W3, - 5424.7 feet.

Plate 18

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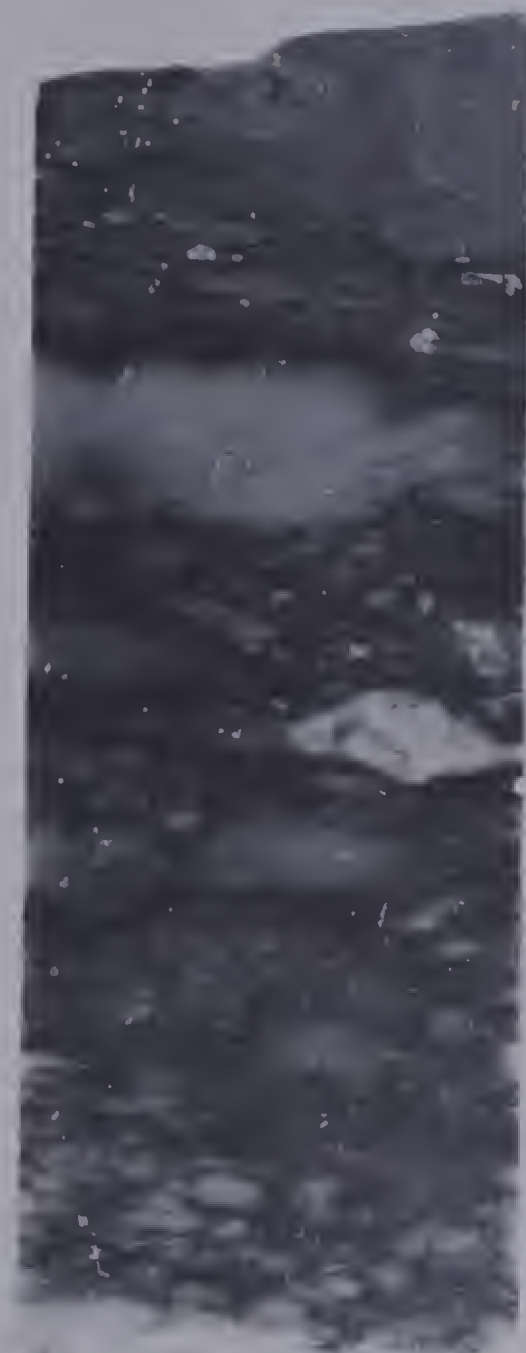

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PLATE 19

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Figure 1 - Wymark Member - Mottled or mosaic anhydrite. The fabric is felty anhydrite with patches of bacillar anhydrite. Some of the anhydrite patches are partially enclosed by dolomitized micrite. Tidewater Morse Crown No. 1 well, - Lsd. 16-25-16-8W3, - 5026.4 feet.

Figure 2 - Wymark Member - Mottled to nodular anhydrite. The rock is similar to that of figure 1, but some of the anhydrite patches are completely enveloped by the dolomitized micrite. Tide-water Morse Crown No. 1 well, -
Lsd. 16-25-16-8W3, - 5032.0 feet - 5032.4 feet.

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PLATE 20

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Figure 1 - Upper Member - Birdbear Formation. This specimen illustrates anhydrite which appears to have developed in association with highly argillaceous carbonate material. As it developed the anhydrite appears to have pushed the carbonate aside resulting in distortion of the bedding within the carbonate. This specimen appears to be a good example of an early stage of interstitial anhydrite development. Tidewater Morse Crown No. 1 well, -
Lsd. 16-25-16-8W3, - 4769.0 feet.

Figure 2 - Wymark Member - Photomicrograph illustrating bacillar anhydrite. Crossed nicols, 44X. Royalite General American Coleville Water Disposal Well No. 1, -
Lsd. 15-31-31-23W3, - 3728.0 feet.

Figure 3 - Wymark Member - Photomicrograph illustrating felty anhydrite fabric in nodular anhydrite. Crossed nicols, 45X. Tidewater Eastend Crown No. 1 well, -
Lsd. 15-11-6-20W3, - 6080.0 feet.

Plate 20

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PLATE 21

Figure 1 - Wymark Member - Photomicrograph illustrating granular anhydrite. Crossed nicols, 45X. Royalite General American Coleville Water Disposal Well No. 1, -
Lsd. 15-31-31-23W3, - 3574.6 feet.

Figure 2 - Wymark Member - Photomicrograph illustrating lathe-shaped or tabular anhydrite in association with felty anhydrite. In this case the lathe-shaped crystals appear to be associated with micro-stylolites. Crossed nicols, 45X. Royalite General American Water Disposal Well No. 1, -
Lsd. 15-31-31-23W3, - 3574.6 feet.

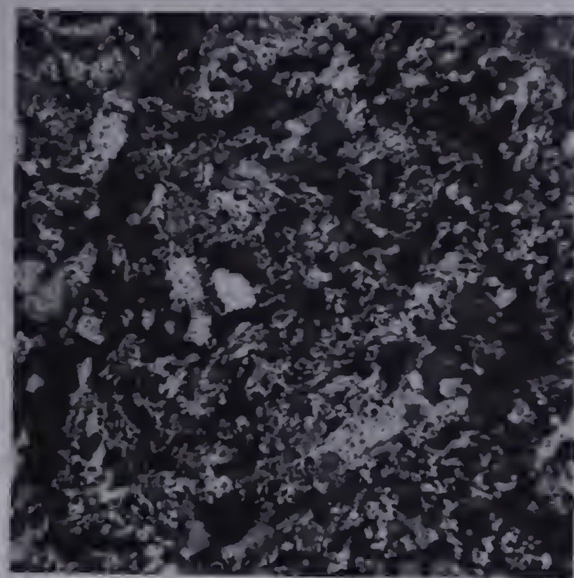
Figure 3 - Wymark Member - Photomicrograph illustrating tabular anhydrite filling a void space of a euhedral to subhedral dolomite inclusion in felty to bacillar anhydrite. Crossed nicols, 45X. Royalite General American Coleville Water Disposal Well No. 1, -
Lsd. 15-31-31-23W3, - 3728.0 feet.

Figure 4 - Wymark Member - Photomicrograph illustrating gneissoid texture in felty anhydrite. Crossed nicols, 45X. Royalite General American Coleville Water Disposal Well No. 1, -
Lsd. 15-31-31-23W3, - 3710.0 feet.

Figure 5 - Wymark Member - Photomicrograph illustrating gneissoid texture wrapped around a dolomite inclusion. The inclusion is beyond the lower edge of the photomicrograph, but the scattered dolomite rhombs in the lower portion of the illustration given evidence to its presence. Crossed nicols, 45X. Royalite General American Coleville Water Disposal Well No. 1, - Lsd. 15-31-31-23W3, - 3710.0 feet.

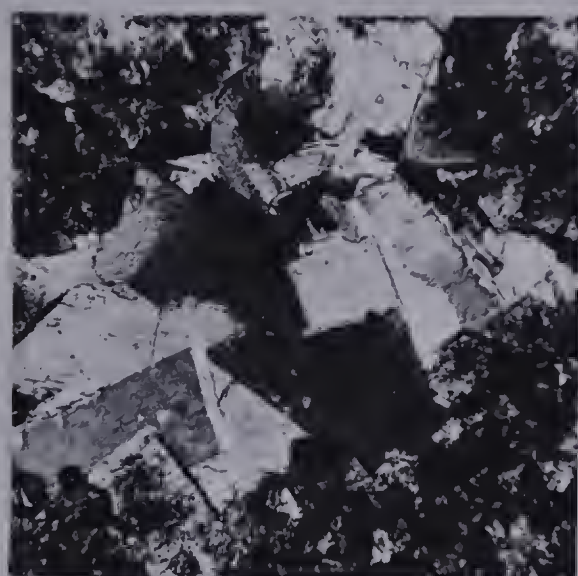
Figure 6 - Wymark Member - Photomicrograph illustrating felty anhydrite, dolomite rhombs and insoluble residue near the interface between a dolomite inclusion and the anhydrite. Cross nicols, 45X. Royalite General American Coleville Water Disposal Well No. 1, - Lsd. 15-31-31-23W3, - 3694.0 feet.

Plate 21



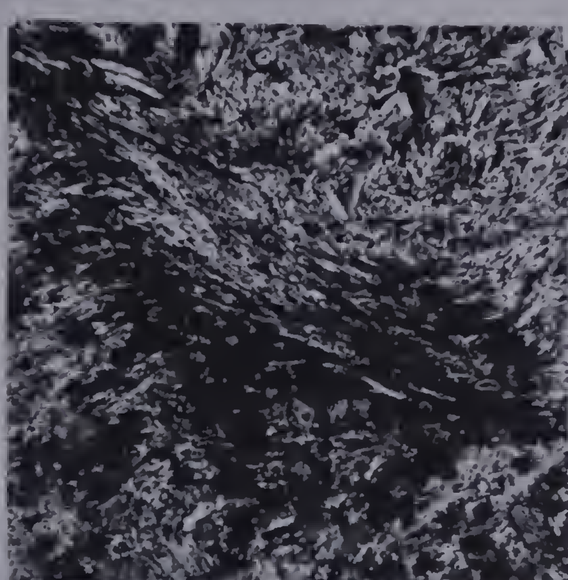
1

2



3

4

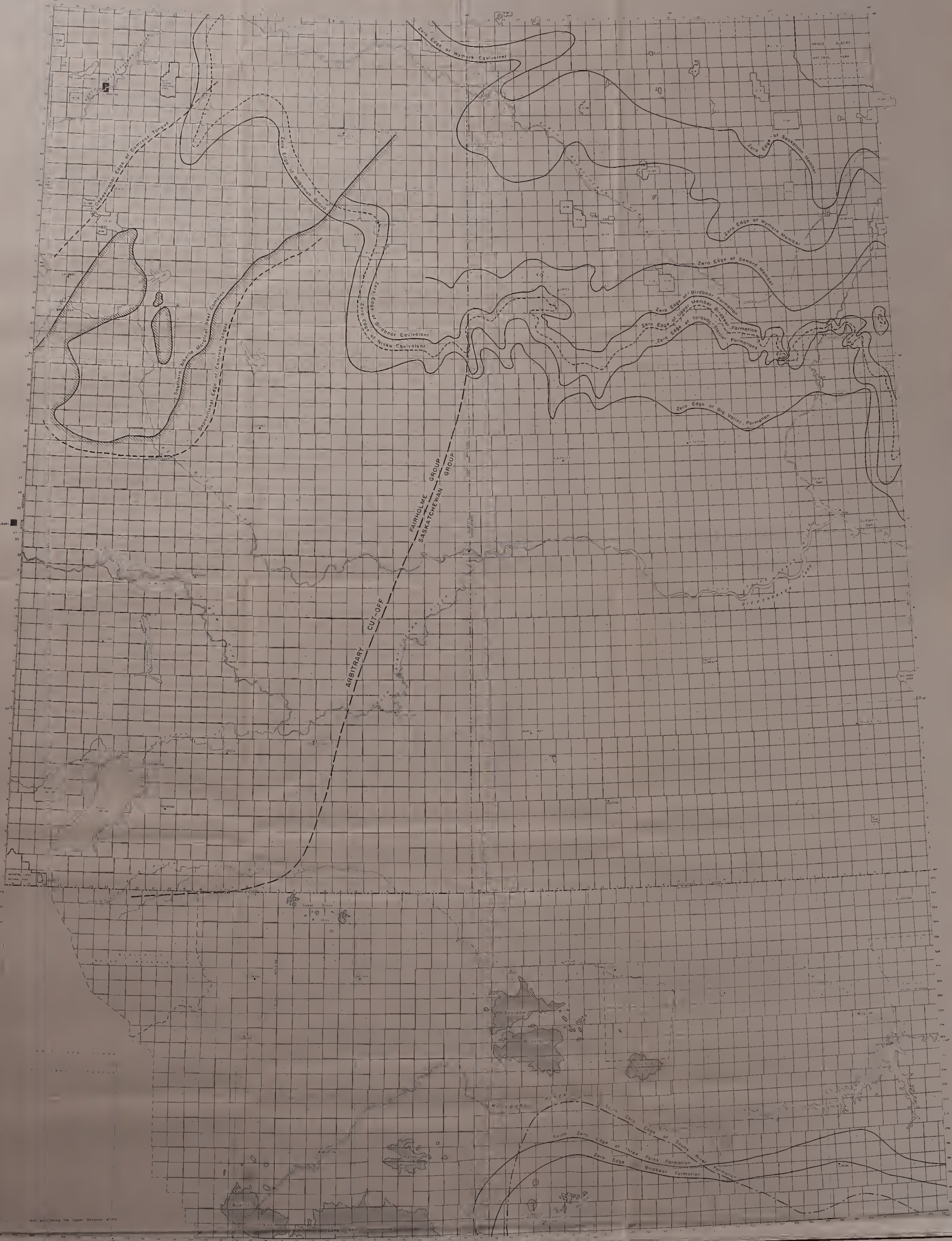


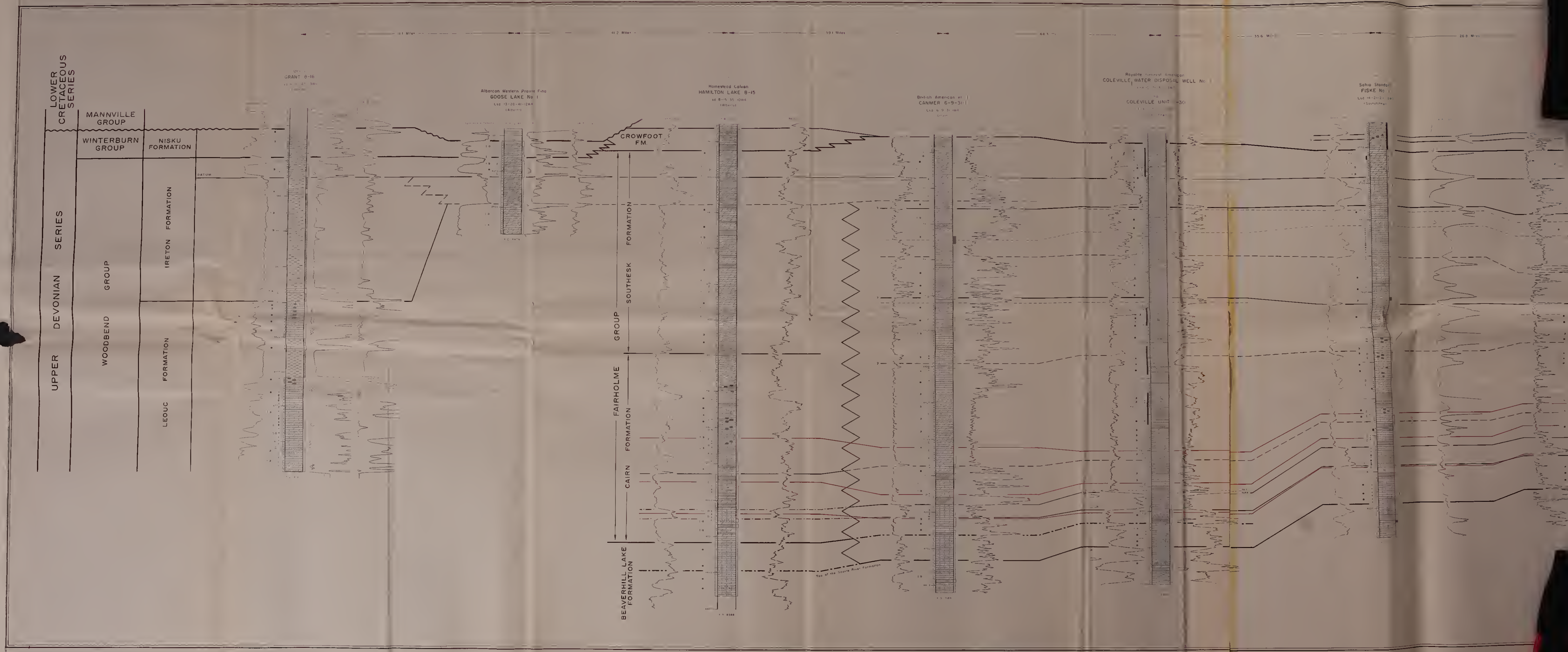
5

6

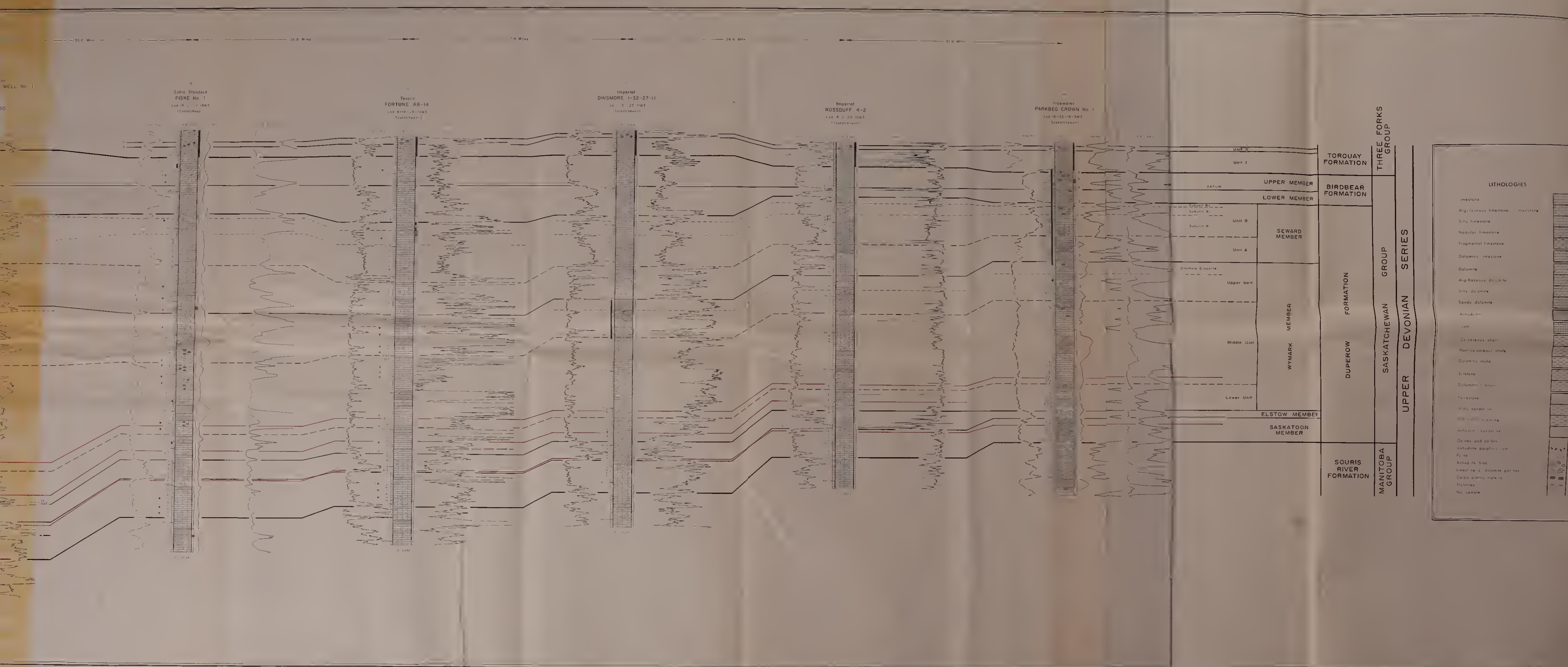
SUBCROP MAP
of the
UPPER DEVONIAN STRATA
in
WESTERN SASKATCHEWAN and ADJACENT AREAS

Figure 2
D. M. Kent





LOWER CRETACEOUS SERIES
MANNVILLE GROUP
WINTERBURN GROUP
NISKU FORMATION
UPPER DEVONIAN SERIES
WOODBEND GROUP
IRETON FORMATION
LEDUC FORMATION
DATUM
GRANT 8-16
GOOSE LAKE No. 1
HAMILTON LAKE 8-15
CROWFOOT FM.
SOUTHESK FORMATION
FAIRHOLME GROUP
CAIRN FORMATION
BEAVERHILL LAKE FORMATION
CANMER 6-9-31-1
COLEVILLE WATER DISPOSAL WELL No. 1
FISKE No. 1



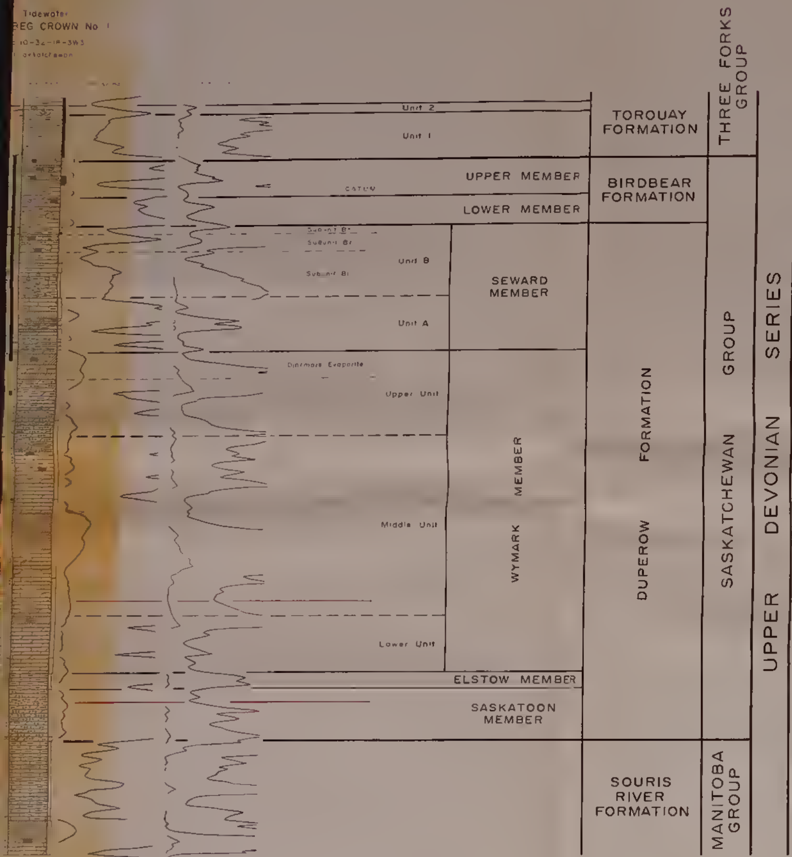
WELL No. 1
Sohio Standard
FISKE No. 1
(Saskatchewan)
Texaco
FORTUNE A8-14
(Saskatchewan)
Imperial
DINSMORE 1-32-27-11
(Saskatchewan)
Imperial
ROSSDUFF 4-2
(Saskatchewan)
Tidewater
PARKBEG CROWN No. 1
Lsd 10-32-16-3W3
(Saskatchewan)
Unit 2
Unit 1
DATUM
UPPER MEMBER
LOWER MEMBER
Unit B
Unit A
SEWARD MEMBER
Upper Unit
Middle Unit
Lower Unit
WYMARK MEMBER
ELSTOW MEMBER
SASKATOON MEMBER
TOROUAY FORMATION
BIRDBEAR FORMATION
DUPEROW FORMATION
SOURIS RIVER FORMATION
THREE FORKS GROUP
SASKATCHEWAN GROUP
MANITOBA GROUP
UPPER DEVONIAN SERIES
LITHOLOGIES
Argillaceous limestone, marlstone
Silty limestone
Nodular limestone
Fragmental limestone
Dolomitic limestone
Dolomite
Argillaceous dolomite
Silty dolomite
Sandy dolomite
Calcareous shale
Non-calcareous shale
Dolomitic shale
Siltstone
Oolites and pellets
Pyrite
Anhydrite blebs
Stylolites
No sample

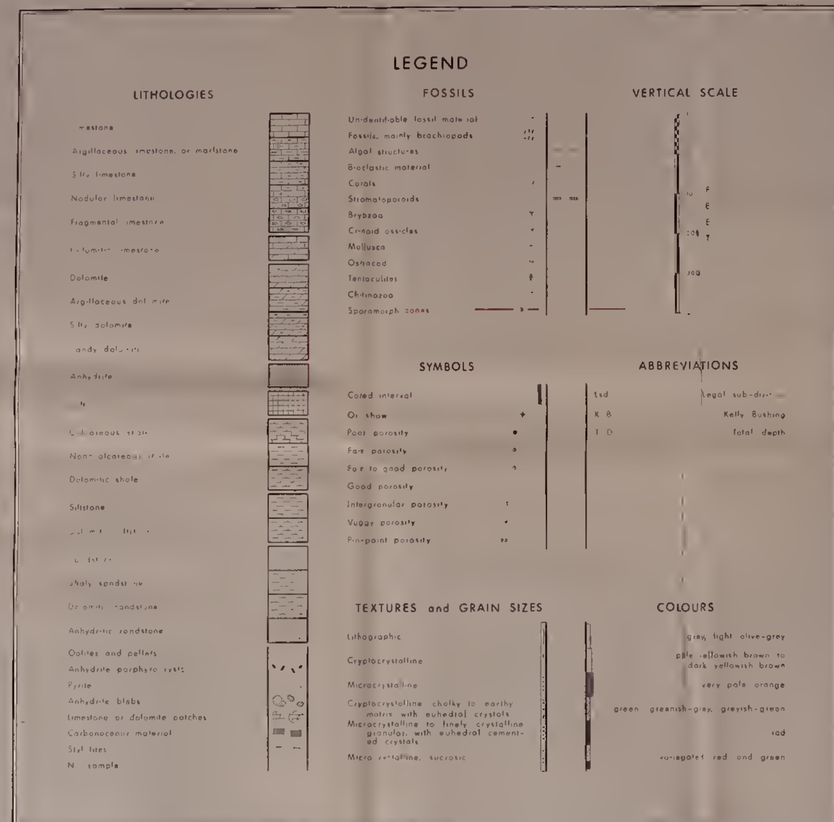
Figure 3

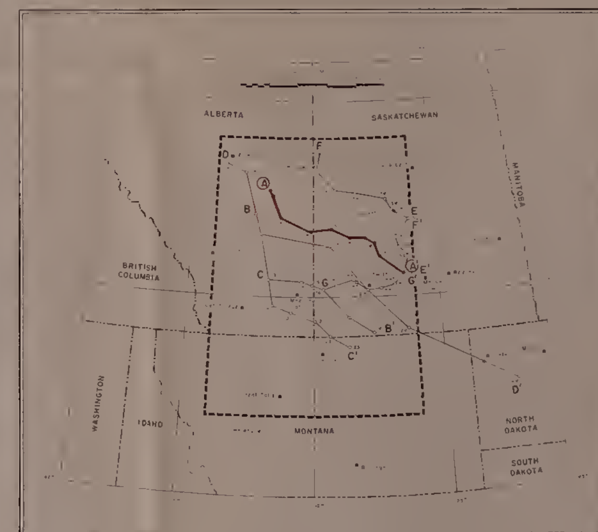
D. M. Kent

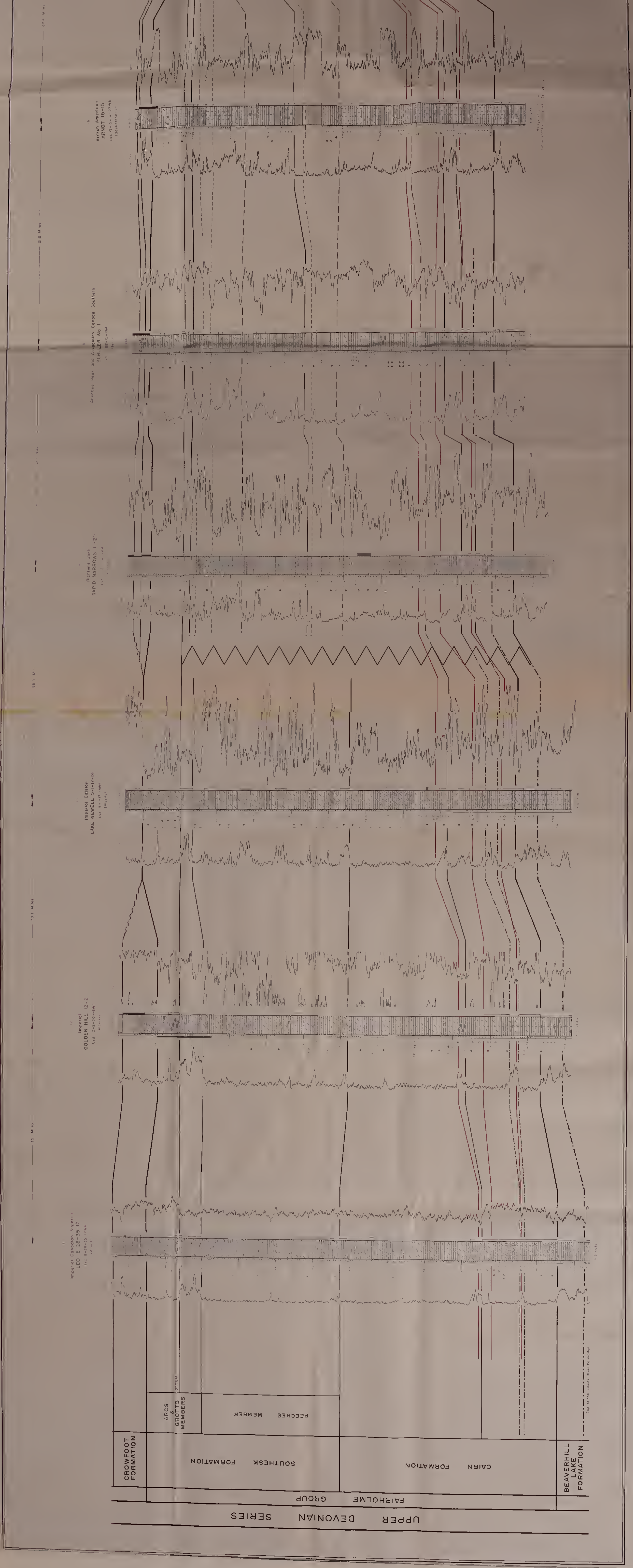
EAST-WEST STRATIGRAPHIC CROSS SECTION (A-A') of the SASKATCHEWAN GROUP in WESTERN SASKATCHEWAN and ADJACENT AREAS

Union GRANT B-16 ⟵⟶ Tidewater PARKBEG CROWN No. 1

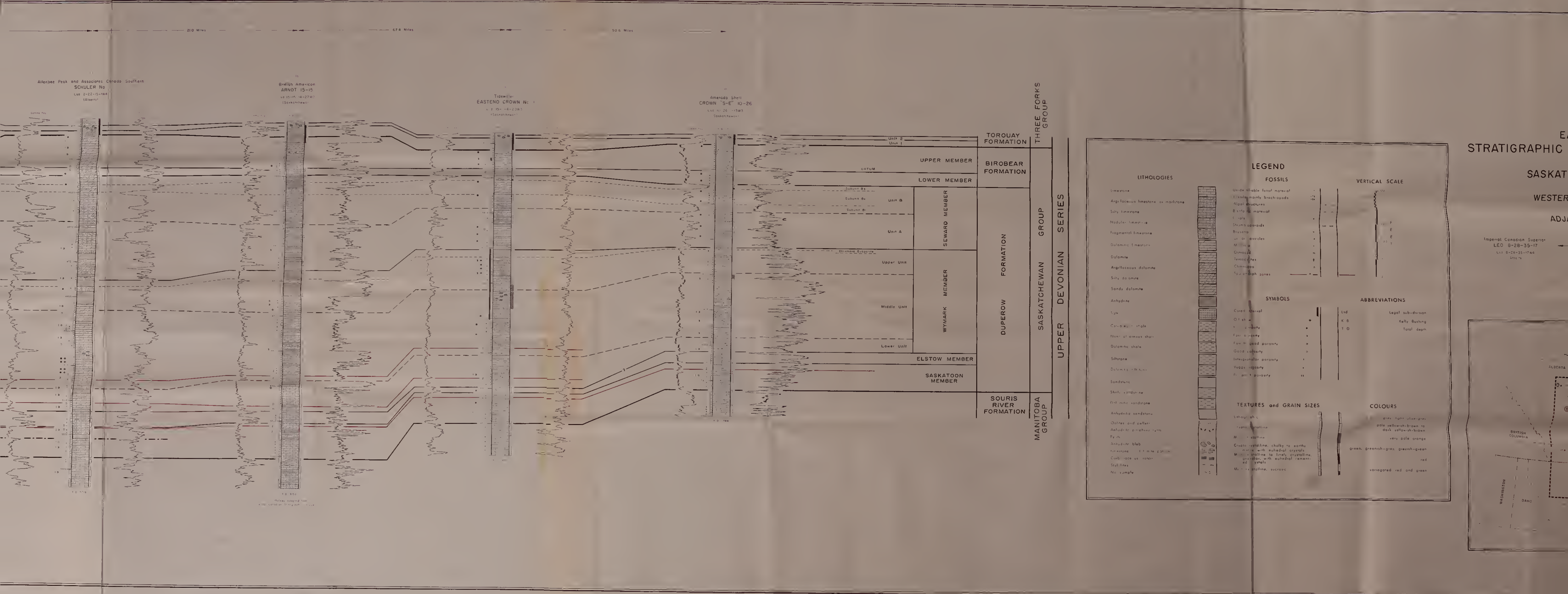








UPPER DEVONIAN SERIES
FAIRHOLME GROUP
CROWFOOT FORMATION
SOUTHESK FORMATION
ARCS & GROTTO MEMBERS
PEECHEE MEMBER
CAIRN FORMATION
BEAVERHILL LAKE FORMATION
Imperial Canadian Superior
LEO 8-28-35-17
Imperial
GOLDEN HILL 12-2
Imperial Cal
LAKE NEWELL 5-1-17-14
Richfield Shell
RAPID NARROWS 11-21
Amerada Petroleum Associates Canada Southern
SCHULER No. 1
British American
ARNOT 15-15
29.7 Miles
21.0 Miles



STRATIGRAPHIC
SASKAT
WESTER
ADJ
Imperial Canadian Superior
LEO 8-28-35-17
Allenbee Peak and Associates Canada Southern
SCHULER No
British American
ARNDT 15-15
Tidewater
EASTEND CROWN No. 1
Amerada Shell
CROWN "S-E" 10-26
210 Miles
67.4 Miles
50.6 Miles
THREE FORKS GROUP
TORQUAY FORMATION
Unit 2
Unit 1
BIROBEAR FORMATION
UPPER MEMBER
DATUM
LOWER MEMBER
SASKATCHEWAN GROUP
DUPEROW FORMATION
SEWARD MEMBER
Unit B
Unit A
WYMARK MEMBER
Upper Unit
Middle Unit
Lower Unit
ELSTOW MEMBER
SASKATOON MEMBER
MANITOBA GROUP
SOURIS RIVER FORMATION
UPPER DEVONIAN SERIES
LEGEND
LITHOLOGIES
FOSSILS
VERTICAL SCALE
SYMBOLS
ABBREVIATIONS
Legal sub-division
Kelly Bushing
Total depth
TEXTURES and GRAIN SIZES
COLOURS
Limestone
Dolomite
Anhydrite
Siltstone
Sandstone
No sample
BRITISH COLUMBIA
WASHINGTON
IDAHO
ALBERTA

Figure 4

D. M. Kent

EAST–WEST STRATIGRAPHIC CROSS SECTION (B–B')

of the

SASKATCHEWAN GROUP

in

WESTERN SASKATCHEWAN

and

ADJACENT AREAS

Imperial Canadian Superior LEO 8-28-35-17 ⟵⟶ Amerada Shell CROWN "S-E" 10-26

UPPER DEVONIAN SERIES		
THREE FORKS GROUP	TORQUAY FORMATION	
SASKATCHEWAN GROUP	BIRDBEAR FORMATION	
SASKATCHEWAN GROUP	DUPEROW FORMATION	
MANITOBA GROUP	SOURIS RIVER FORMATION	

LEGEND

LITHOLOGIES

- Limestone
- Argillaceous limestone, or marlstone
- Silty limestone
- Nodular limestone
- Fragmental limestone
- Dolomitic limestone
- Dolomite
- Argillaceous dolomite
- Silty dolomite
- Sandy dolomite
- Anhydrite
- Salt
- Calcareous shale
- Non-calcareous shale
- Dolomitic shale
- Siltstone
- Dolomitic siltstone
- Sandstone
- Shaly sandstone
- Dolomitic sandstone
- Anhydritic sandstone
- Oolites and pellets
- Anhydrite porphyro rysts
- Pyrite
- Anhydrite blebs
- Limestone or dolomite patches
- Carbonaceous material
- Stylolites
- No sample

FOSSILS

- Unidentifiable fossil material
- Fossils mainly brachiopods
- Algal structures
- Bioclastic material
- Corals
- Stromatoporoids
- Bryozoa
- Crinoid ossicles
- Mollusca
- Ostracod
- Tentaculites
- Chitinozoa
- Sporomorph zones

VERTICAL SCALE

SYMBOLS

- Cored interval
- Oil show
- Poor porosity
- Fair porosity
- Fair to good porosity
- Good porosity
- Intergranular porosity
- Viggy porosity
- Pin-point porosity

ABBREVIATIONS

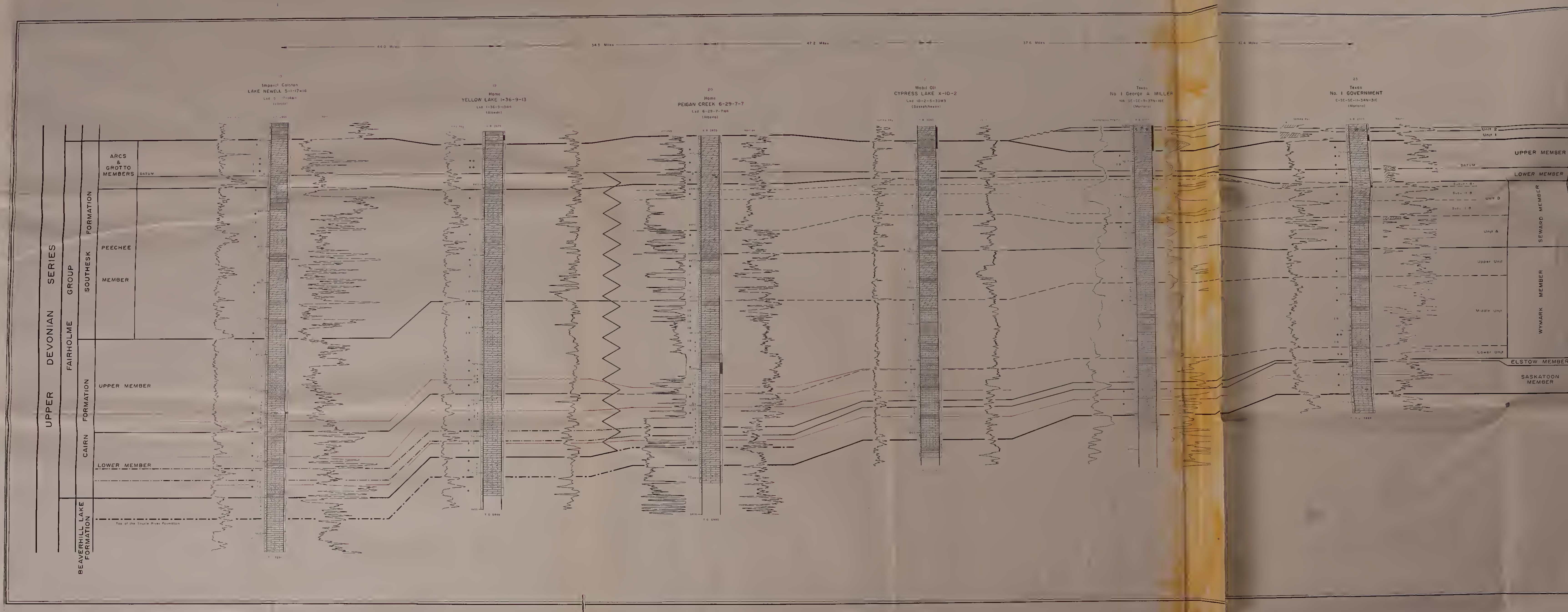
- Lsd — Legal sub-division
- K B — Kelly Bushing
- T D — Total depth

TEXTURES and GRAIN SIZES

- Lithographic
- Cryptocrystalline
- Microcrystalline
- Cryptocrystalline, chalky to earthy matrix with euhedral crystals
- Microcrystalline to finely crystalline, granular, with euhedral cemented crystals
- Microcrystalline, sucrosic

COLOURS

- grey, light olive-grey
- pale yellowish-brown to dark yellowish-brown
- very pale orange
- green, greenish-grey, grayish-green
- red
- variegated red and green



44.0 Miles
34.5 Miles
47.2 Miles
37.6 Miles
42.4 Miles
Imperial Carston
LAKE NEWELL 5-1-17-16
Home
YELLOW LAKE 1-36-9-13
Lsd 1-36-9-13W4
(Alberta)
29
Home
PEIGAN CREEK 6-29-7-7
Lsd 6-29-7-7W4
(Alberta)
Mobil Oil
CYPRESS LAKE X-10-2
(Saskatchewan)
Texas
No. 1 George A. MILLER
(Montana)
23
Texas
No. 1 GOVERNMENT
(Montana)
UPPER DEVONIAN SERIES
FAIRHOLME GROUP
SOUTHESK FORMATION
ARCS & GROTTO MEMBERS
DATUM
PEECHEE MEMBER
CAIRN FORMATION
UPPER MEMBER
LOWER MEMBER
BEAVERHILL LAKE FORMATION
Top of the Souris River Formation
Unit 2
Unit 1
UPPER MEMBER
LOWER MEMBER
SEWARD MEMBER
Unit B
Unit A
WYMARK MEMBER
Upper Unit
Middle Unit
Lower Unit
ELSTOW MEMBER
SASKATOON MEMBER

Figure 5

D. M. Kent

EAST-WEST STRATIGRAPHIC CROSS SECTION (C-C')

of the

SASKATCHEWAN GROUP

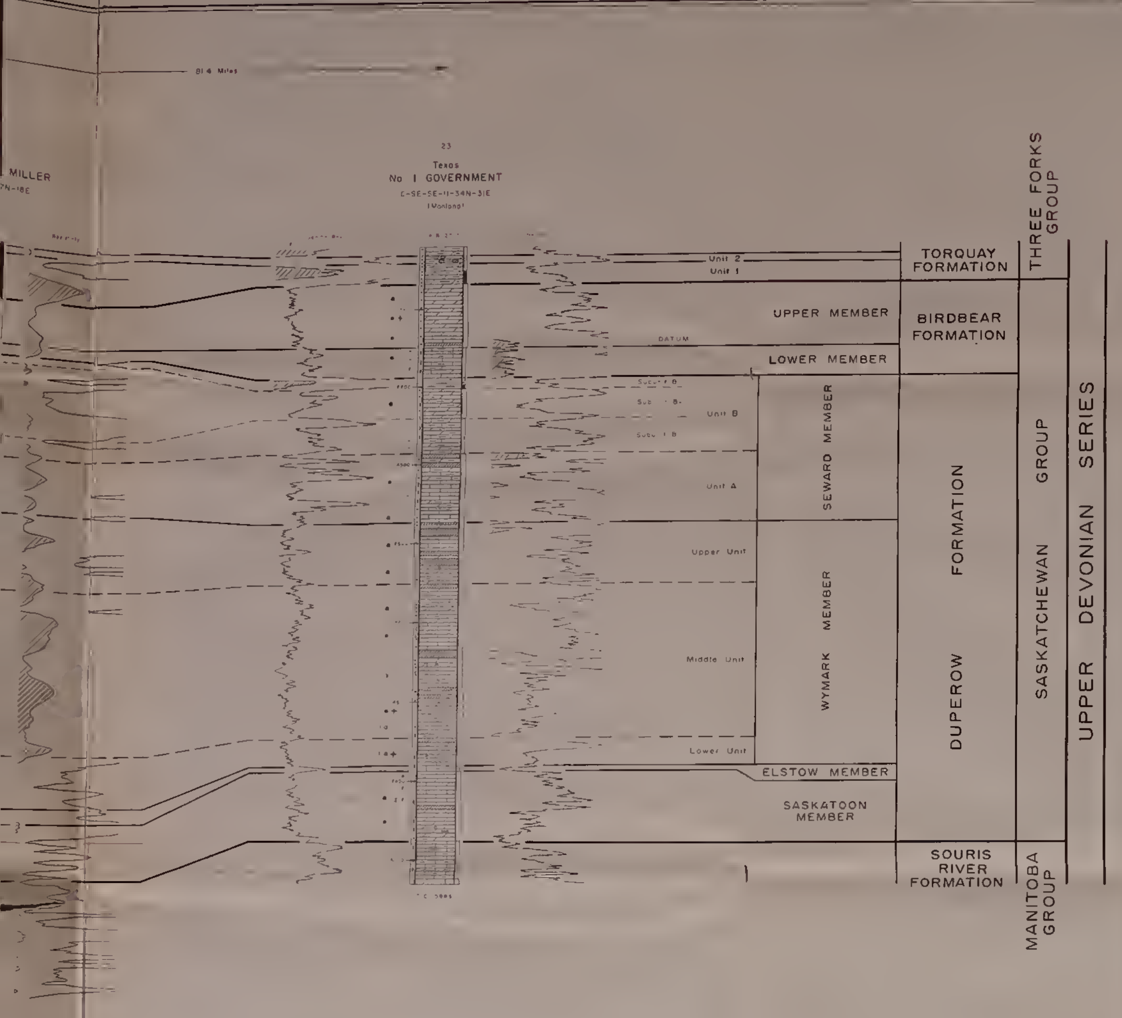
in

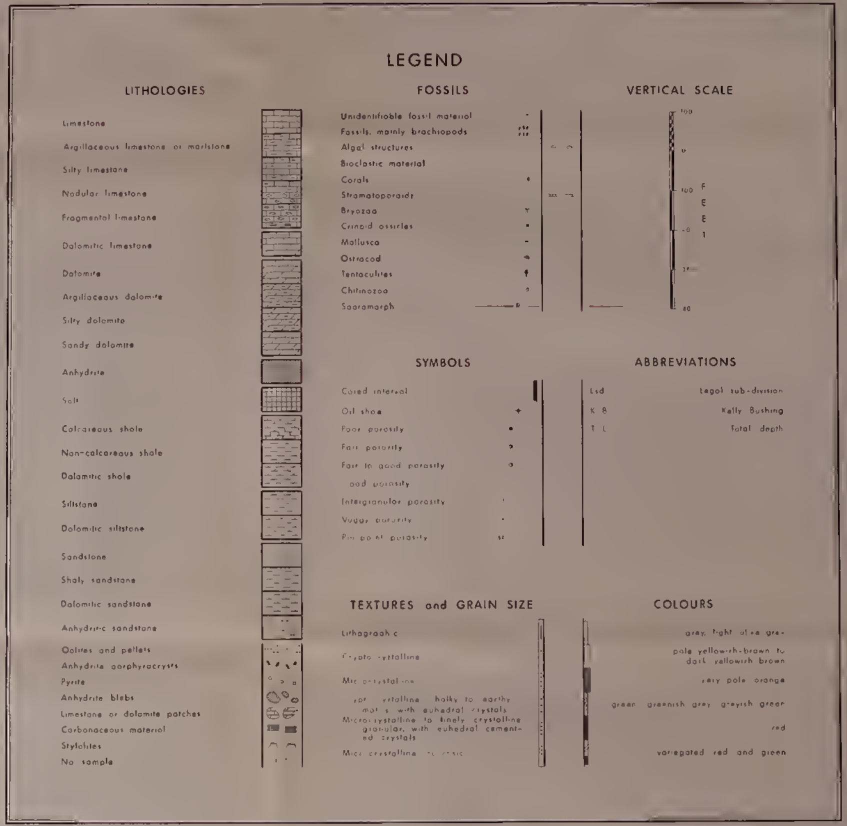
WESTERN SASKATCHEWAN

and

ADJACENT AREAS

Imperial Calstan LAKE NEWELL 5-1-17-14 ⟵⟶ Texas No. 1 GOVERNMENT C-SE-SE 11-34N-31E (Montana)





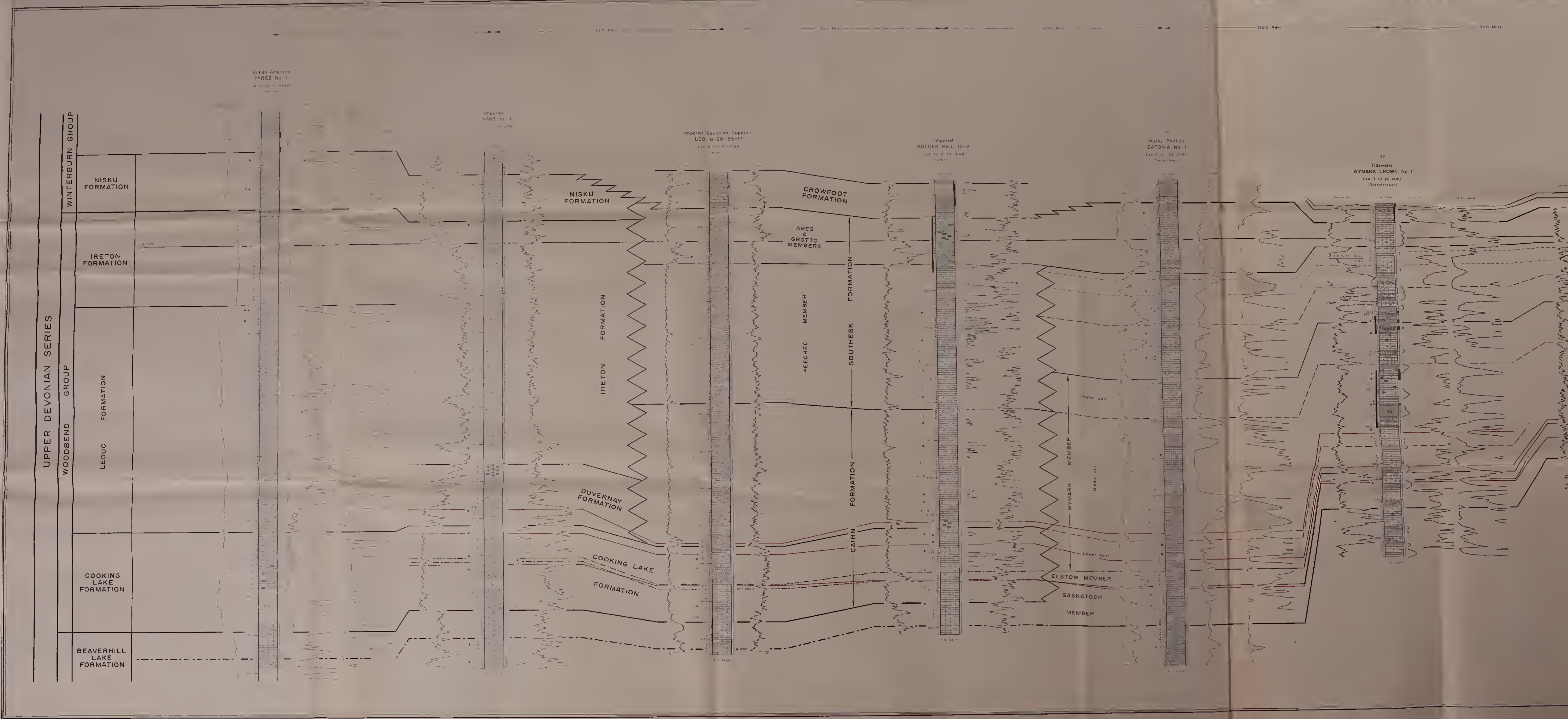

UPPER DEVONIAN SERIES
WINTERBURN GROUP
WOODBEND GROUP
NISKU FORMATION
IRETON FORMATION
LEDUC FORMATION
COOKING LAKE FORMATION
BEAVERHILL LAKE FORMATION
DATUM
British American PYRCZ No. 1
Imperial UNANT No. 1
Imperial Canadian Superior LEO 8-28-35-17
Imperial GOLDEN HILL 12-2
Husky Phillips EATONIA No. 1
Tidewater WYMARK CROWN No. 1
(Saskatchewan)
NISKU FORMATION
IRETON FORMATION
DUVERNAY FORMATION
COOKING LAKE FORMATION
CROWFOOT FORMATION
ARCS & GROTTO MEMBERS
PEECHEE MEMBER
SOUTHESK FORMATION
CAIRN FORMATION
WYMARK MEMBER
Upper Unit
Middle Unit
Lower Unit
ELSTOW MEMBER
SASKATOON MEMBER

Figure 6
D. M. Kent

EAST-WEST STRATIGRAPHIC CROSS SECTION (D-D')

of the

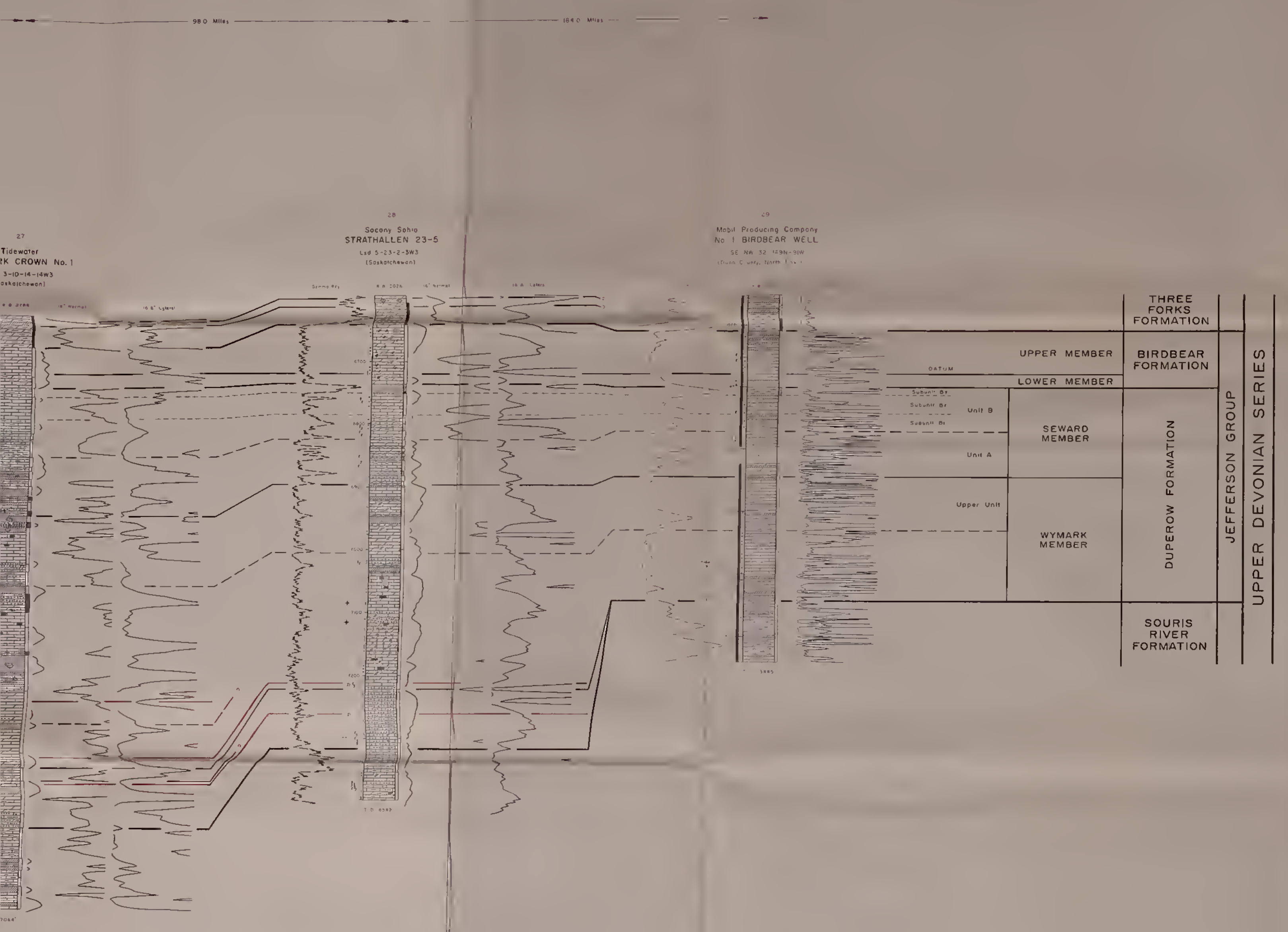
SASKATCHEWAN GROUP

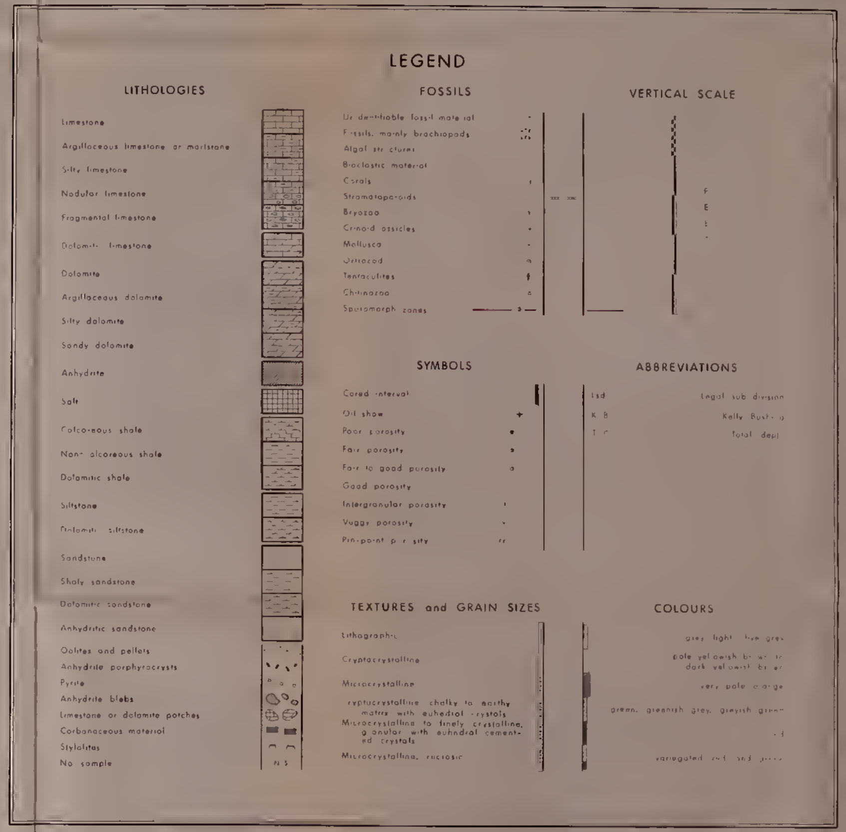
in

WESTERN SASKATCHEWAN

and

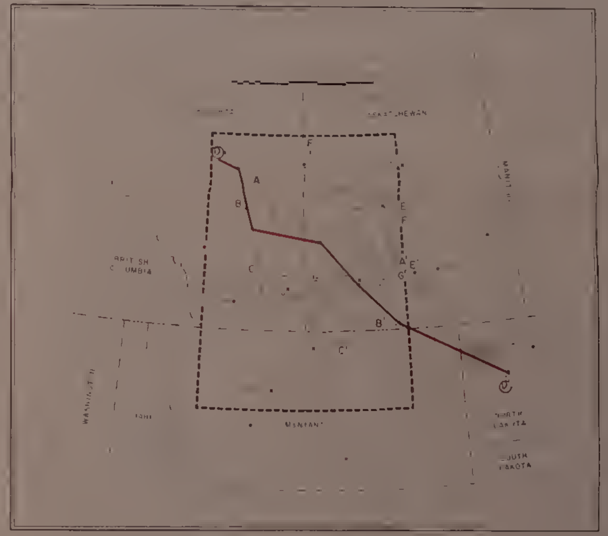
ADJACENT AREAS

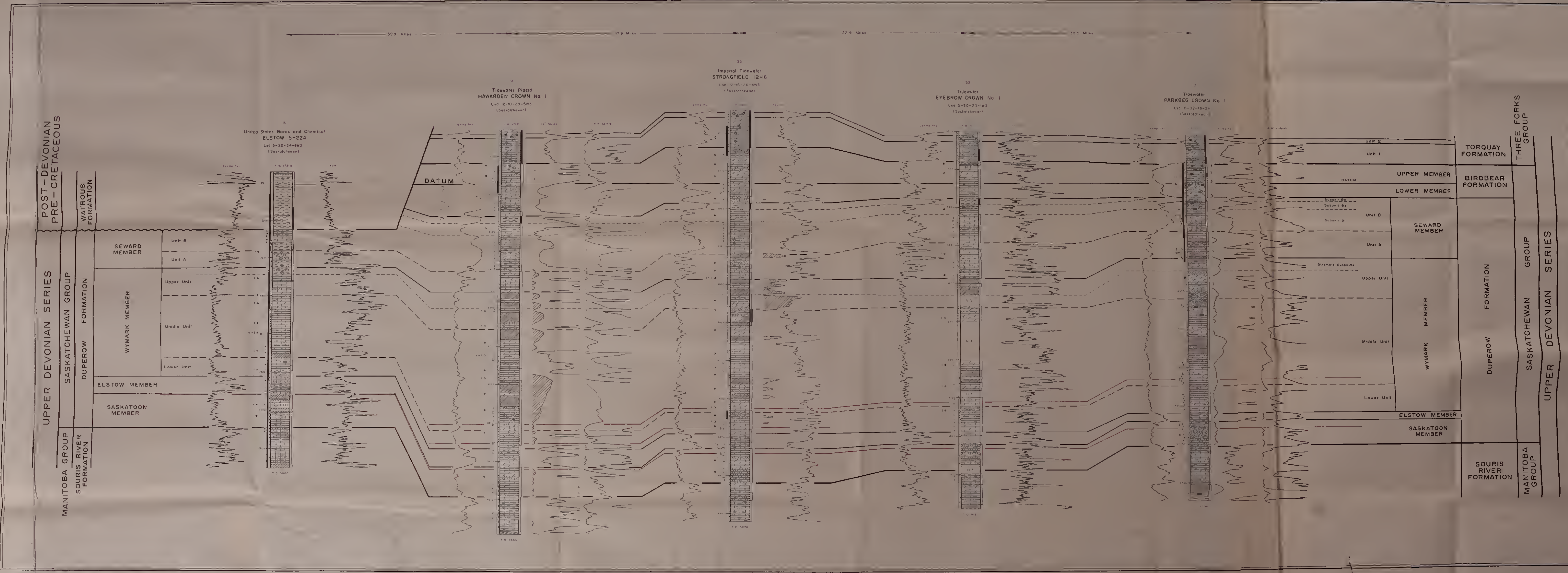




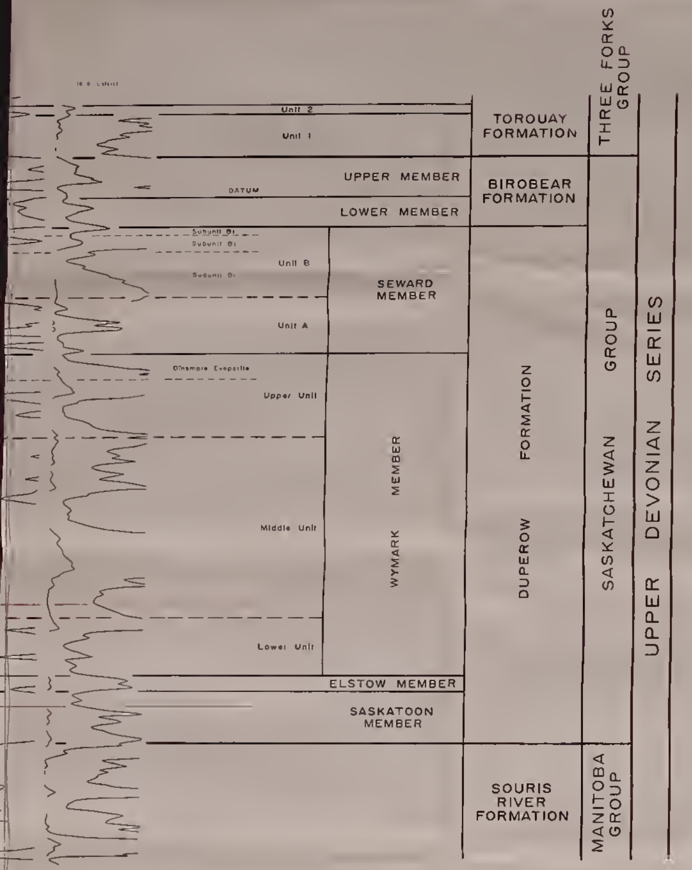
British American
PRYCZ No. 1

Mobil Producing Company
No. 1 BIRDBEAR WELL





United States Borax and Chemical
ELSTOW 5-22A
Tidewater Placid
HAWARDEN CROWN No. 1
Imperial Tidewater
STRONGFIELD 12-16
Tidewater
EYEBROW CROWN No. 1
Tidewater
PARKBEG CROWN No. 1
DATUM
POST-DEVONIAN PRE-CRETACEOUS
WATROUS FORMATION
UPPER DEVONIAN SERIES
SASKATCHEWAN GROUP
DUPEROW FORMATION
SEWARD MEMBER
WYMARK MEMBER
ELSTOW MEMBER
SASKATOON MEMBER
MANITOBA GROUP
SOURIS RIVER FORMATION
Unit B
Unit A
Upper Unit
Middle Unit
Lower Unit
THREE FORKS GROUP
TORQUAY FORMATION
BIRDBEAR FORMATION
UPPER MEMBER
LOWER MEMBER
Unit 2
Unit 1



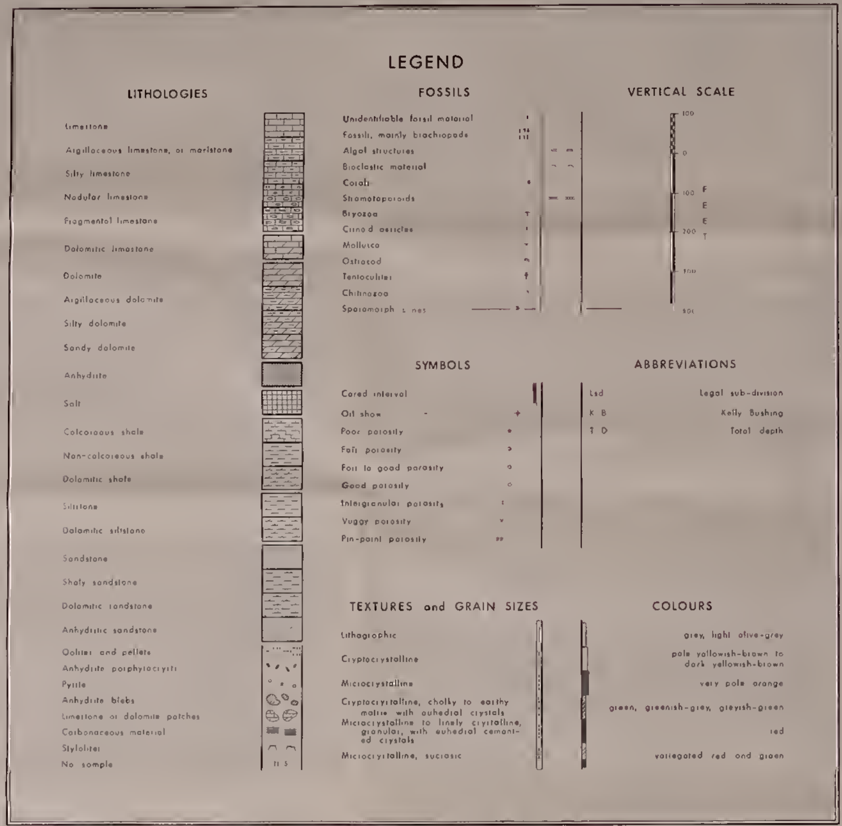


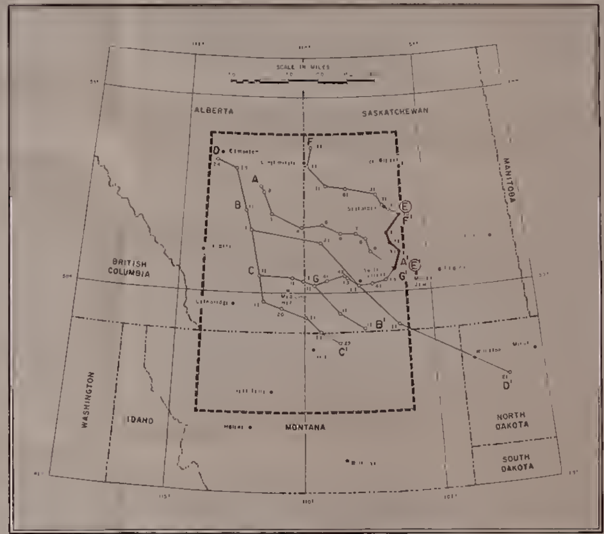
Figure 7

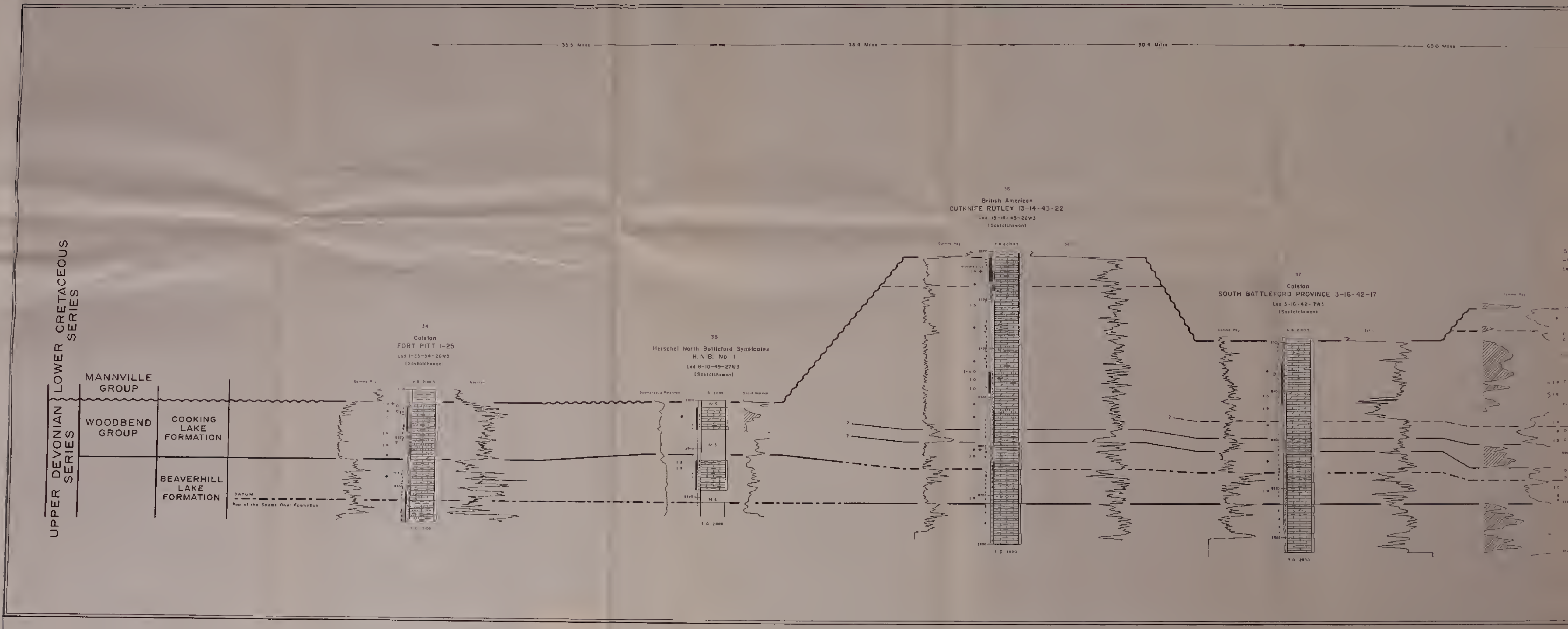
D. M. Kent

NORTH-SOUTH
STRATIGRAPHIC CROSS SECTION (E-E')
of the
SASKATCHEWAN GROUP
in
WESTERN SASKATCHEWAN
and
ADJACENT AREAS

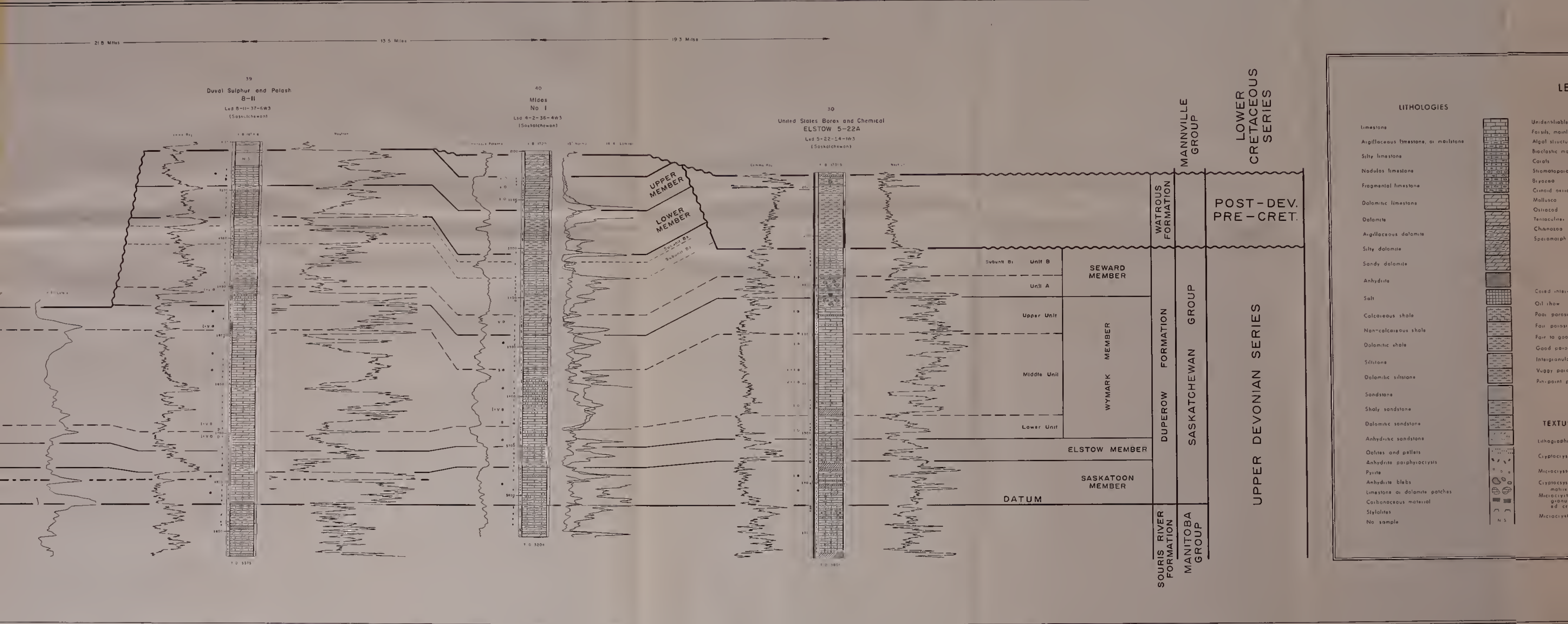
United States Borax and Chemical
ELSTOW 5-22A
Lsd 5-22-34-1W3
(Saskatchewan)

Tidewater
PARKBEG CROWN No. 1
Lsd 10-32-16-3W3
(Saskatchewan)





33.5 Miles
38.4 Miles
30.4 Miles
60.0 Miles
LOWER CRETACEOUS SERIES
UPPER DEVONIAN SERIES
MANNVILLE GROUP
WOODBEND GROUP
COOKING LAKE FORMATION
BEAVERHILL LAKE FORMATION
DATUM
Top of the Souris River Formation
34
Calstan
FORT PITT 1-25
Lsd 1-25-54-26W3
(Saskatchewan)
35
Herschel North Battleford Syndicates
H.N.B. No 1
Lsd 6-10-49-27W3
(Saskatchewan)
36
British American
CUTKNIFE RUTLEY 13-14-43-22
Lsd 13-14-43-22W3
(Saskatchewan)
37
Calstan
SOUTH BATTLEFORD PROVINCE 3-16-42-17
Lsd 3-16-42-17W3
(Saskatchewan)



21.8 Miles
13.5 Miles
19.3 Miles
39
Duval Sulphur and Potash
8-11
Lsd 8-11-37-6W3
(Saskatchewan)
40
Midas
No 1
Lsd 4-2-36-4W3
(Saskatchewan)
30
United States Borax and Chemical
ELSTOW 5-22A
Lsd 5-22-34-1W3
(Saskatchewan)
UPPER MEMBER
LOWER MEMBER
Subunit B2
Subunit B1
Subunit B1
Unit B
Unit A
Upper Unit
Middle Unit
Lower Unit
SEWARD MEMBER
WYMARK MEMBER
ELSTOW MEMBER
SASKATOON MEMBER
DATUM
WATROUS FORMATION
DUPEROW FORMATION
SOURIS RIVER FORMATION
MANNVILLE GROUP
SASKATCHEWAN GROUP
MANITOBA GROUP
LOWER CRETACEOUS SERIES
POST-DEV. PRE-CRET.
UPPER DEVONIAN SERIES
LITHOLOGIES
Limestone
Argillaceous limestone, or marlstone
Silty limestone
Nodular limestone
Fragmental limestone
Dolomitic limestone
Dolomite
Argillaceous dolomite
Silty dolomite
Sandy dolomite
Anhydrite
Salt
Calcareous shale
Non-calcareous shale
Dolomitic shale
Siltstone
Dolomitic siltstone
Sandstone
Shaly sandstone
Dolomitic sandstone
Anhydritic sandstone
Oolites and pellets
Anhydrite porphyrocrysts
Pyrite
Anhydrite blebs
Limestone or dolomite patches
Carbonaceous material
Stylolites
No sample
N.S.
Mollusca
Ostracod
Chitinozoa
Oil show

LEGEND

LITHOLOGIES

- Limestone
- Argillaceous limestone, or marlstone
- Silty limestone
- Nodular limestone
- Fragmental limestone
- Dolomitic limestone
- Dolomite
- Argillaceous dolomite
- Silty dolomite
- Sandy dolomite
- Anhydrite
- Salt
- Calcareous shale
- Non-calcareous shale
- Dolomitic shale
- Siltstone
- Dolomitic siltstone
- Sandstone
- Shaly sandstone
- Dolomitic sandstone
- Anhydritic sandstone
- Oolites and pellets
- Anhydrite porphyrocrysts
- Pyrite
- Anhydrite blebs
- Limestone or dolomite patches
- Carbonaceous material
- Stylolites
- No sample — N S

FOSSILS

- Unidentifiable fossil material
- Fossils, mainly brachiopods
- Algal structures
- Bioclastic material
- Corals
- Stromatoporoids
- Bryozoa
- Crinoid ossicles
- Mollusca
- Ostracod
- Tentaculites
- Chitinozoa
- Sporomorph

VERTICAL SCALE

100 — 0 — 100 — 200 — 300 — 400 FEET

SYMBOLS

- Cored interval
- Oil show
- Poor porosity
- Fair porosity
- Fair to good porosity
- Good porosity
- Intergranular porosity
- Vuggy porosity
- Pin-point porosity

ABBREVIATIONS

Lsd	Legal sub-division
K B	Kelly Bushing
T D	Total depth

TEXTURES and GRAIN SIZES

- Lithographic
- Cryptocrystalline
- Microcrystalline
- Cryptocrystalline, chalky to earthy matrix with euhedral crystals
- Microcrystalline to finely crystalline, granular, with euhedral cemented crystals
- Microcrystalline sucrosic

COLOURS

- grey, light olive-grey
- pale yellowish-brown to dark yellowish-brown
- very pale orange
- green, greenish-grey, greyish-green
- red
- variegated red and green

EAST-WEST STRATIGRAPHIC CROSS SECTION (F-F') of the SASKATCHEWAN GROUP in WESTERN SASKATCHEWAN and ADJACENT AREAS

Calstan FORT PITT 1-25 Lsd 1-25-54-26W3 (Saskatchewan)	⟵⟶	United States Borax and Chemical ELSTOW 5-22A Lsd 5-22-34-1W3 (Saskatchewan)

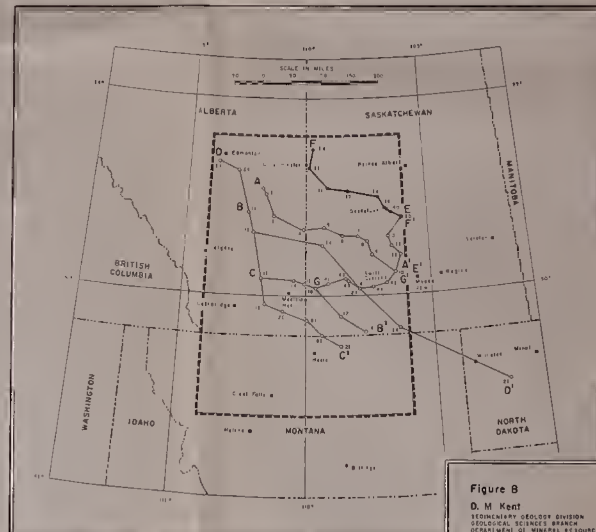
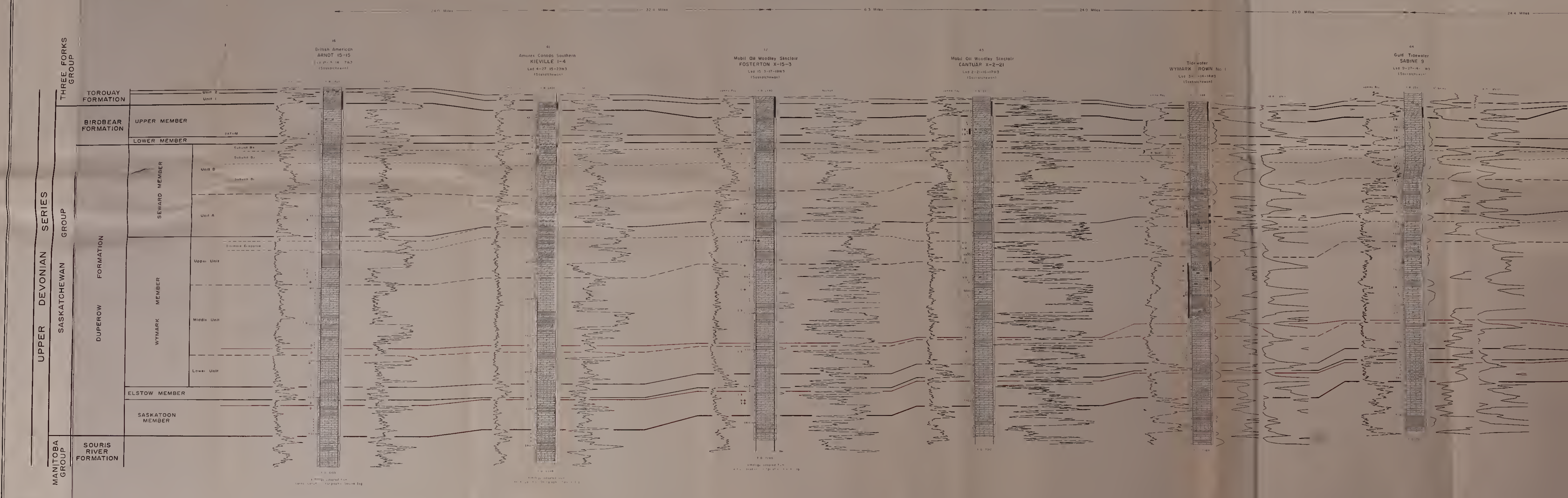
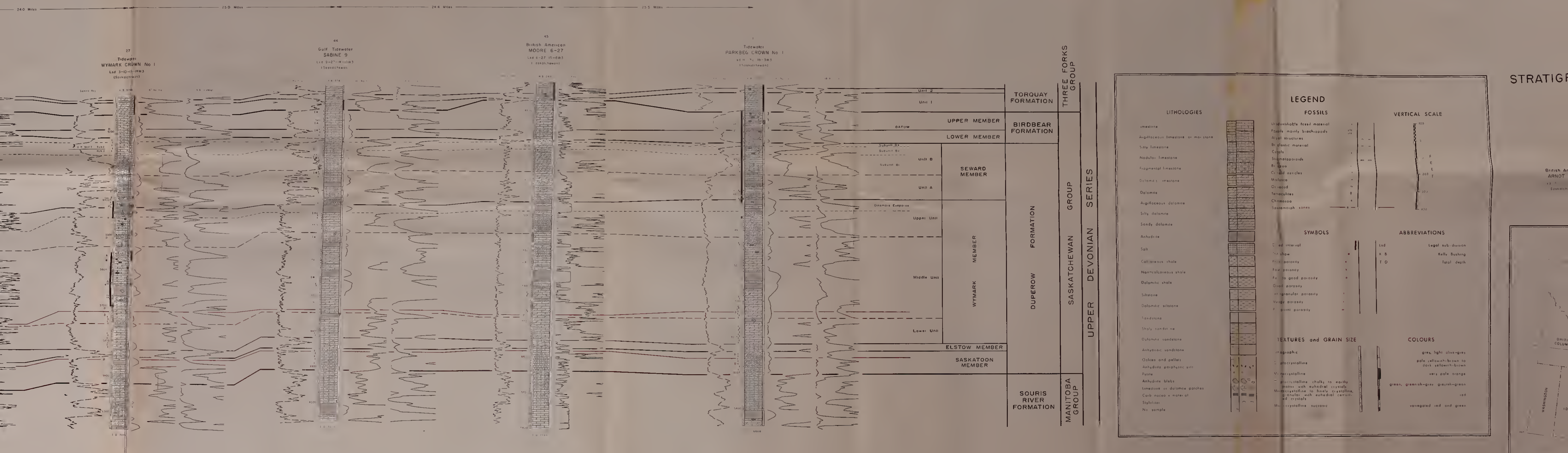


Figure 8

D. M Kent
SEDIMENTARY GEOLOGY DIVISION
GEOLOGICAL SCIENCES BRANCH
DEPARTMENT OF MINERAL RESOURCES
GOVERNMENT OF SASKATCHEWAN



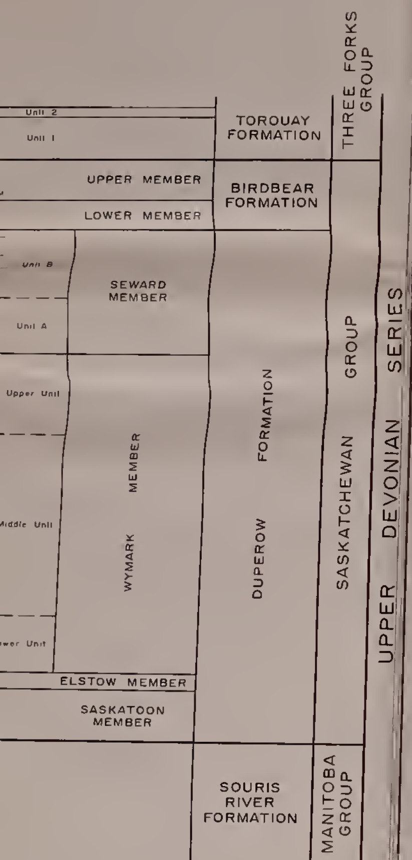
24.0 Miles
32.4 Miles
6.5 Miles
24.0 Miles
25.0 Miles
24.4 Miles
UPPER DEVONIAN SERIES
SASKATCHEWAN GROUP
THREE FORKS GROUP
MANITOBA GROUP
TORQUAY FORMATION
BIRDBEAR FORMATION
UPPER MEMBER
LOWER MEMBER
DUPEROW FORMATION
SEWARD MEMBER
Unit B
Unit A
WYMARK MEMBER
Upper Unit
Middle Unit
Lower Unit
ELSTOW MEMBER
SASKATOON MEMBER
SOURIS RIVER FORMATION
Unit 2
Unit 1
DATUM
16
British American
ARNOT 15-15
(Saskatchewan)
41
Amures Canada Southern
KIEVILLE 1-4
Lsd 4-27 15-23W3
(Saskatchewan)
12
Mobil Oil Woodley Sinclair
FOSTERTON X-15-3
Lsd 15 3-17-18W3
(Saskatchewan)
43
Mobil Oil Woodley Sinclair
CANTUAR X-2-21
Lsd 2-21-16-17W3
(Saskatchewan)
Tidewater
WYMARK ROWN No. 1
(Saskatchewan)
44
Gulf Tidewater
SABINE 9
(Saskatchewan)

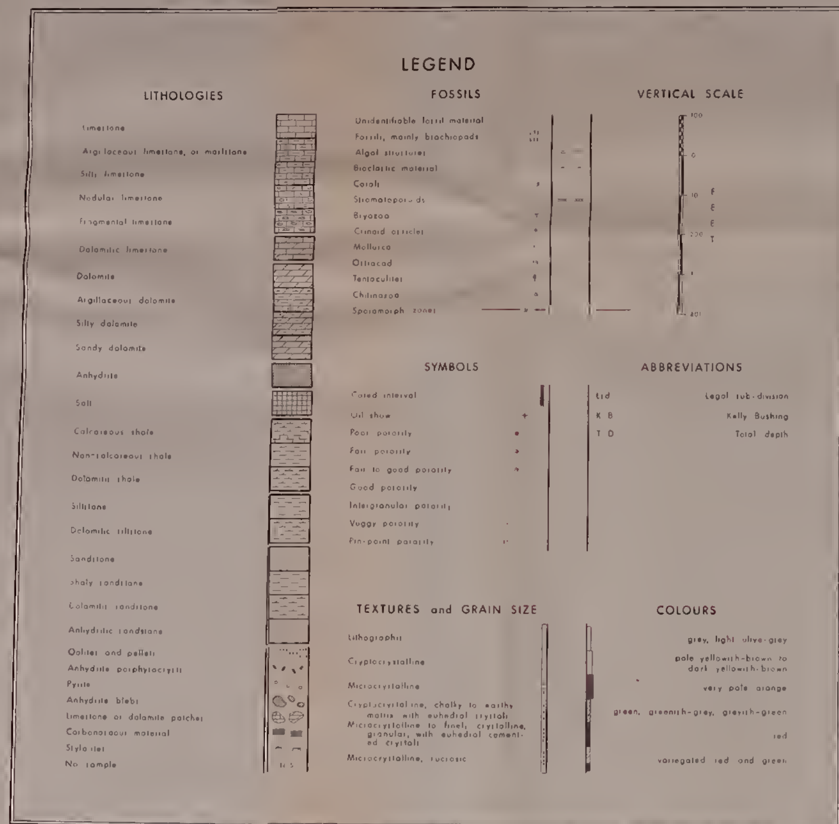


Tidewater
WYMARK CROWN No. 1
Gulf Tidewater
SABINE 9
British American
MOORE 6-27
Tidewater
PARKBEG CROWN No. 1
Unit 2
Unit 1
DATUM
Unit B
Unit A
Upper Unit
Middle Unit
Lower Unit
UPPER MEMBER
LOWER MEMBER
SEWARD MEMBER
WYMARK MEMBER
ELSTOW MEMBER
SASKATOON MEMBER
TORQUAY FORMATION
BIRDBEAR FORMATION
DUPEROW FORMATION
SOURIS RIVER FORMATION
THREE FORKS GROUP
SASKATCHEWAN GROUP
MANITOBA GROUP
UPPER DEVONIAN SERIES
LEGEND
LITHOLOGIES
Argillaceous limestone or marlstone
Silty limestone
Nodular limestone
Fragmental limestone
Dolomite
Argillaceous dolomite
Silty dolomite
Sandy dolomite
Anhydrite
Salt
Non-calcareous shale
Dolomitic shale
Siltstone
Dolomitic siltstone
Dolomitic sandstone
Oolites and pellets
Pyrite
Anhydrite blebs
Stylolites
No sample
FOSSILS
Unidentifiable fossil material
Fossils mainly brachiopods
Bioclastic material
Stromatoporoids
Mollusca
Tentaculites
Chitinozoa
Sporomorph zones
VERTICAL SCALE
100
200
FEET
SYMBOLS
Fair porosity
Fair to good porosity
Good porosity
Vuggy porosity
ABBREVIATIONS
Lsd
Legal sub-division
K B
Kelly Bushing
T D
Total depth
TEXTURES and GRAIN SIZE
Microcrystalline sucrosic
COLOURS
grey, light olive-grey
pale yellowish-brown to dark yellowish-brown
very pale orange
green, greenish-grey, greyish-green
red
variegated red and green
STRATIG

Figure 9

D M Kent

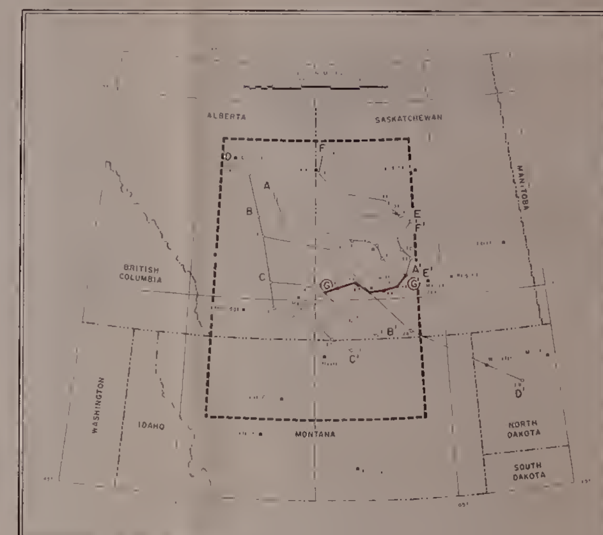




EAST-WEST STRATIGRAPHIC CROSS SECTION (G-G') of the SASKATCHEWAN GROUP in WESTERN SASKATCHEWAN and ADJACENT AREAS

British American
ARNOT 15-15
Lsd 15-15-4-27W3
(Saskatchewan)

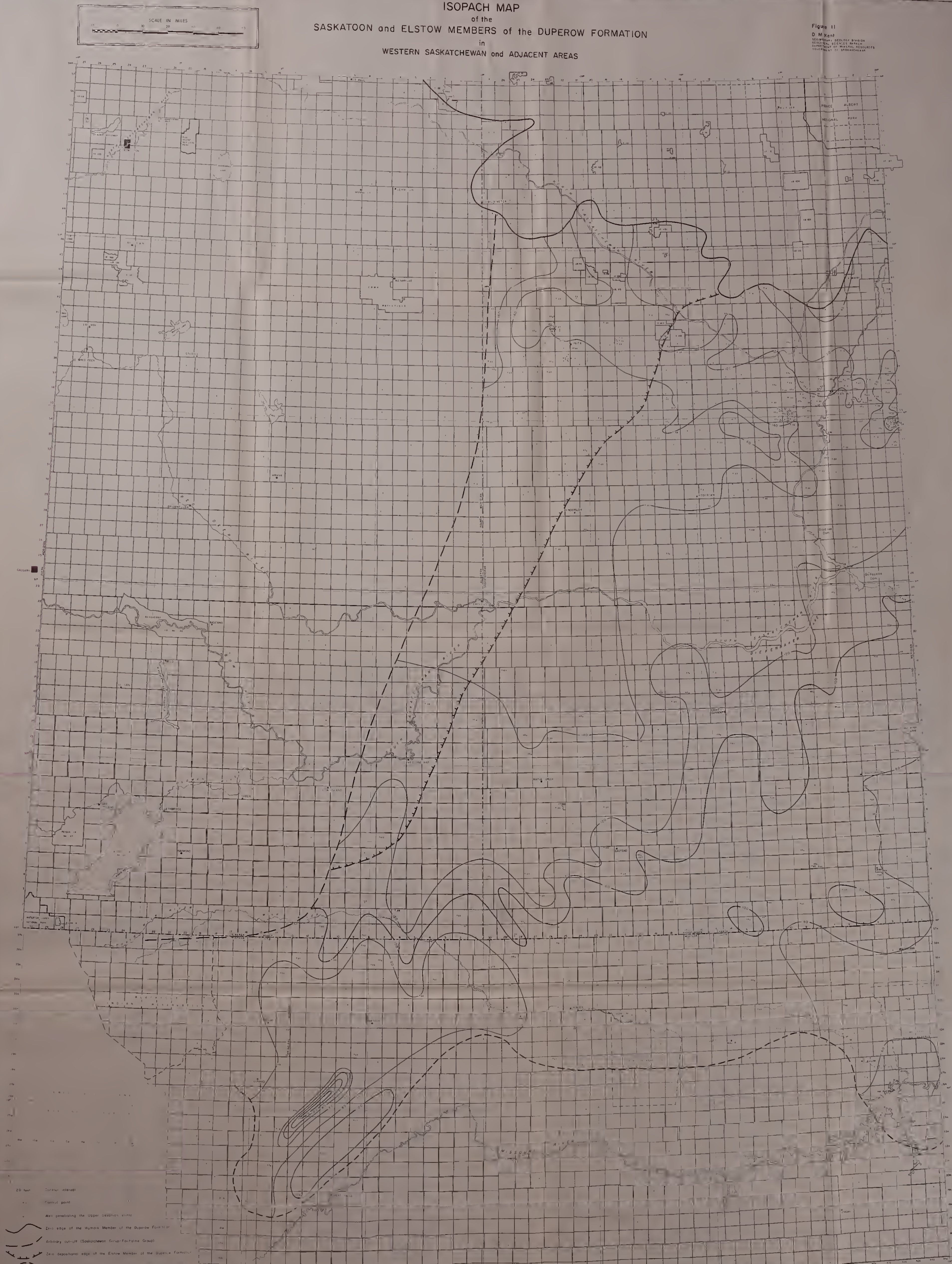
Tidewater
PARKBEG CROWN No. 1
Lsd 10-32-18-3W3
(Saskatchewan)



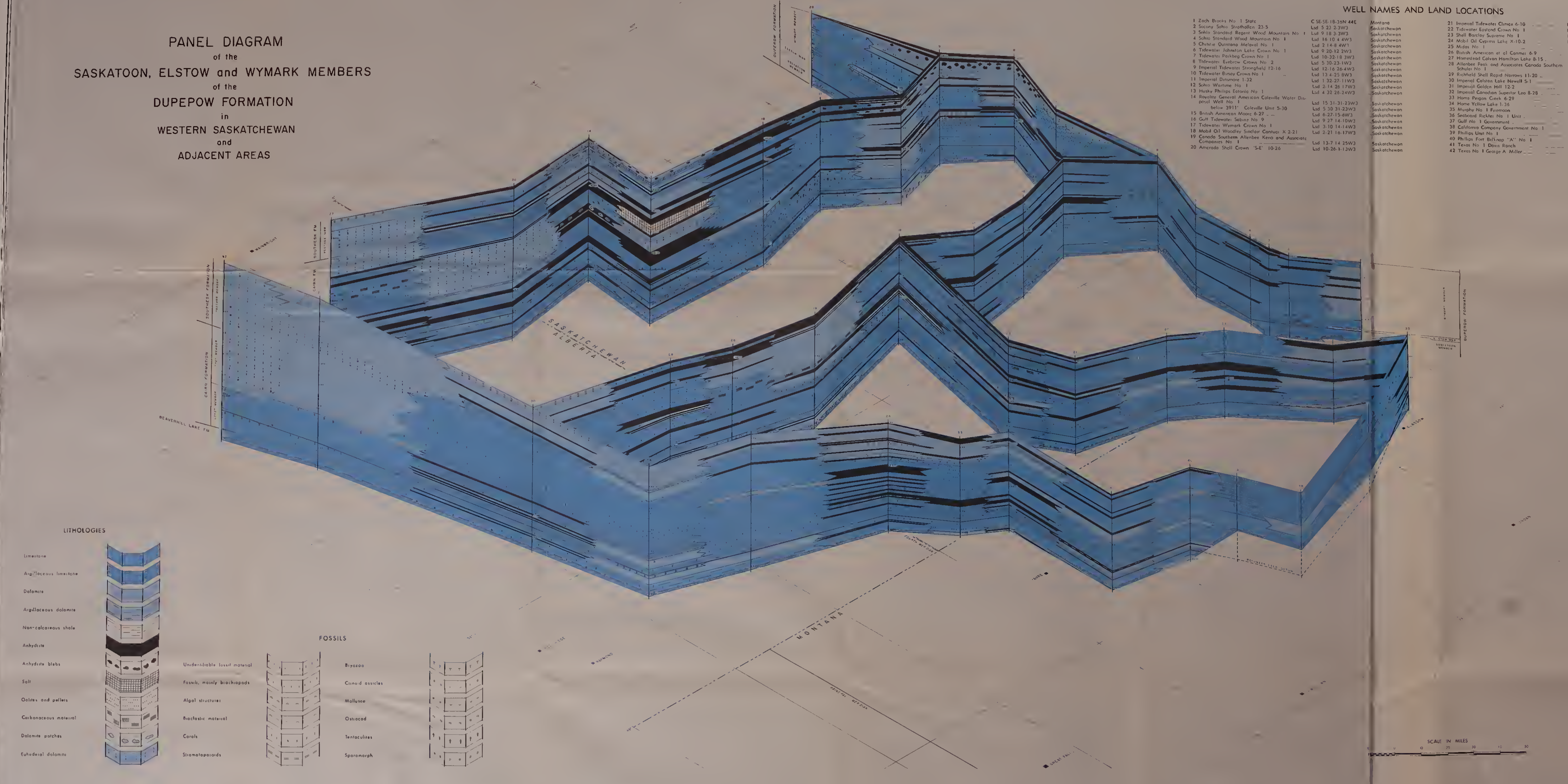
ISOPACH MAP
of the
SASKATOON and ELSTOW MEMBERS of the DUPEROW FORMATION
in
WESTERN SASKATCHEWAN and ADJACENT AREAS

Figure 11

D. M. Kent



PANEL DIAGRAM
of the
SASKATOON, ELSTOW and WYMARK MEMBERS
of the
DUPEPOW FORMATION
in
WESTERN SASKATCHEWAN
and
ADJACENT AREAS



WELL NAMES AND LAND LOCATIONS

1	Zach Brooks No 1 State	C SE-SE-18-36N 44E	Montana
2	Socony Sohio Strathallen 23-5	Lsd 5 23 2-3W3	Saskatchewan
3	Sohio Standard Regent Wood Mountain No 1	Lsd 9 18 3-3W3	Saskatchewan
4	Sohio Standard Wood Mountain No 1	Lsd 16 10 4 4W3	Saskatchewan
5	Christie Quintana Meleval No 1	Lsd 2 14-8 4W3	Saskatchewan
6	Tidewater Johnston Lake Crown No 1	Lsd 9 20-12 2W3	Saskatchewan
7	Tidewater Parkbeg Crown No 1	Lsd 10-32-18 3W3	Saskatchewan
8	Tidewater Eyebrow Crown No 2	Lsd 5 30-23-1W3	Saskatchewan
9	Imperial Tidewater Strongfield 12-16	Lsd 12-16 26-4W3	Saskatchewan
10	Tidewater Birsay Crown No 1	Lsd 13 4-25 8W3	Saskatchewan
11	Imperial Dinsmore 1-32	Lsd 1 32-27-11W3	Saskatchewan
12	Sohio Wartime No 1	Lsd 2-14 26 17W3	Saskatchewan
13	Husky Phillips Eatonia No 1	Lsd 4 32 26-24W3	Saskatchewan
14	Royalite General American Coleville Water Disposal Well No 1	Lsd 15 31-31-23W3	Saskatchewan
	below 3911' Coleville Unit 5-30	Lsd 5 30 31-23W3	Saskatchewan
15	British American Moore 6-27	Lsd 6-27-15-6W3	Saskatchewan
16	Gulf Tidewater Sabine No 9	Lsd 9 27 14-10W3	Saskatchewan
17	Tidewater Wymark Crown No 1	Lsd 3-10 14-14W3	Saskatchewan
18	Mobil Oil Woodley Sinclair Cantuar X 2-21	Lsd 2-21 16-17W3	Saskatchewan
19	Canada Southern Allenbee Keno and Associate Companies No 1	Lsd 13-7 14 25W3	Saskatchewan
20	Amerada Shell Crown 'S-E' 10-26	Lsd 10-26-1-13W3	Saskatchewan
21	Imperial Tidewater Climax 6-10	Lsd 6-10-3-18W3	Saskatchewan
22	Tidewater Eastend Crown No 1	Lsd 5-11-6-20W3	Saskatchewan
23	Shell Barclay Supreme No 1	Lsd 7-2-2-28W3	Saskatchewan
24	Mobil Oil Cypress Lake X-10-2	Lsd 10-2-5-30W3	Saskatchewan
25	Midas No 1	Lsd 4-2-36-4W3	Saskatchewan
26	British American et al Conmei 6-9	Lsd 6-9-31-1W4	Alberta
27	Homestead Colvan Hamilton Lake 8-15	Lsd 8-15-35-10W4	Alberta
28	Allenbee Peak and Associates Canada Southern Schuler No 1	Lsd 2-22-15-1W4	Alberta
29	Richfield Shell Rapid Narrows 11-20	Lsd 11-20-16-4W4	Alberta
30	Imperial Colston Lake Newell 5-1	Lsd 5-1-17-14W4	Alberta
31	Imperial Golden Hill 12-2	Lsd 12-2-30-16W4	Alberta
32	Imperial Canadian Superior Leo 8-28	Lsd 8-28-35-17W4	Alberta
33	Home Peigan Creek 6-29	Lsd 6-29-7-7W4	Alberta
34	Home Yellow Lake 1-36	Lsd 1-36-9-13W4	Alberta
35	Murphy No 1 Firemoon	C-SE-SE-12-30N-41E	Montana
36	Seaboard Rickter No 1 Unit	C-SW-NE-18-32N-38E	Montana
37	Gulf No 1 Government	SW-SW-SW-31-37N-34E	Montana
38	California Company Government No 1	C-NE-NW-33-26N-34E	Montana
39	Phillips Unit No 1	SE-SE-NW-29-23N-26E	Montana
40	Phillips Fort Belknap "A" No 1	SW-NW-3-28N-23E	Montana
41	Texas No 1 Davis Ranch	C-SE-SW-4-29N-18E	Montana
42	Texas No 1 George A Miller	NW-SE-SE-9-37N-18E	Montana

Figure 12

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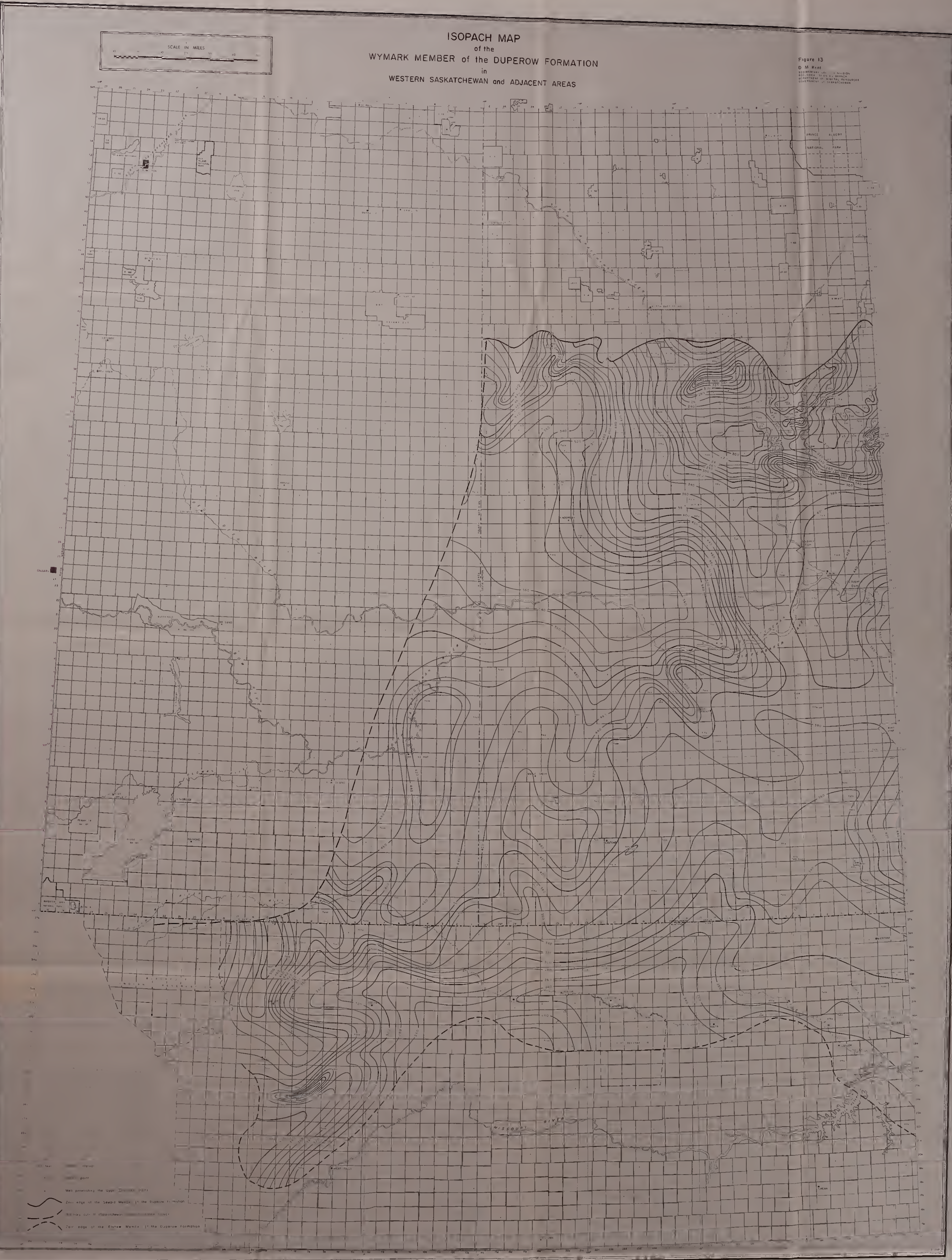
SEDIMENTARY GEOLOGY DIVISION
GEOLOGICAL SCIENCES BRANCH
DEPARTMENT OF MINERAL RESOURCES
GOVERNMENT OF SASKATCHEWAN

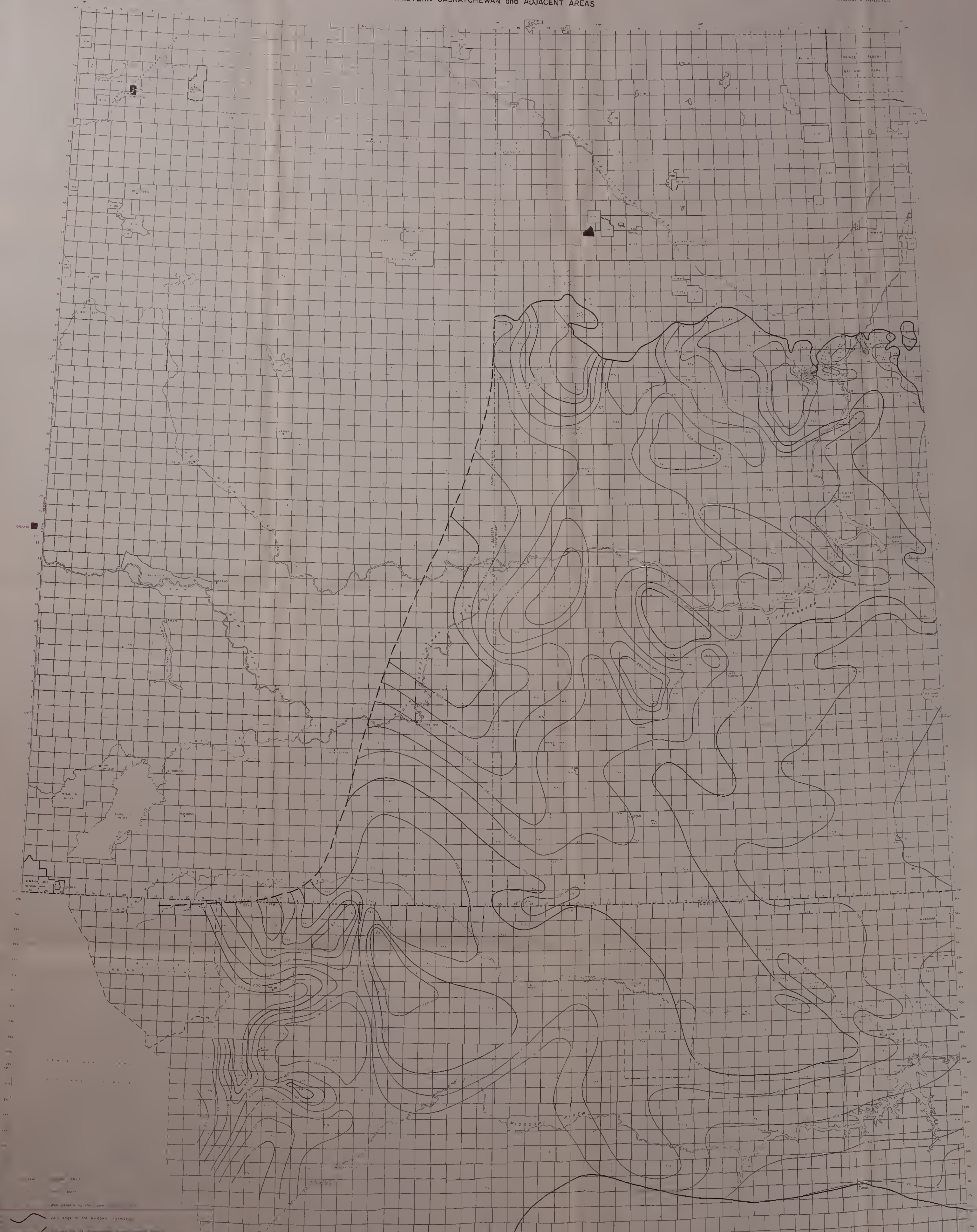

ISOPACH MAP
of the
WYMARK MEMBER of the DUPEROW FORMATION
in
WESTERN SASKATCHEWAN and ADJACENT AREAS
SCALE IN MILES
Figure 13
D M Kent
PRINCE ALBERT
NATIONAL PARK
MISSOURI RIVER
Well penetrating the Upper
edge of the Seward Member of the Duperow Formation
edge of the Elstow Member of the Duperow Formation

SCALE IN MILES

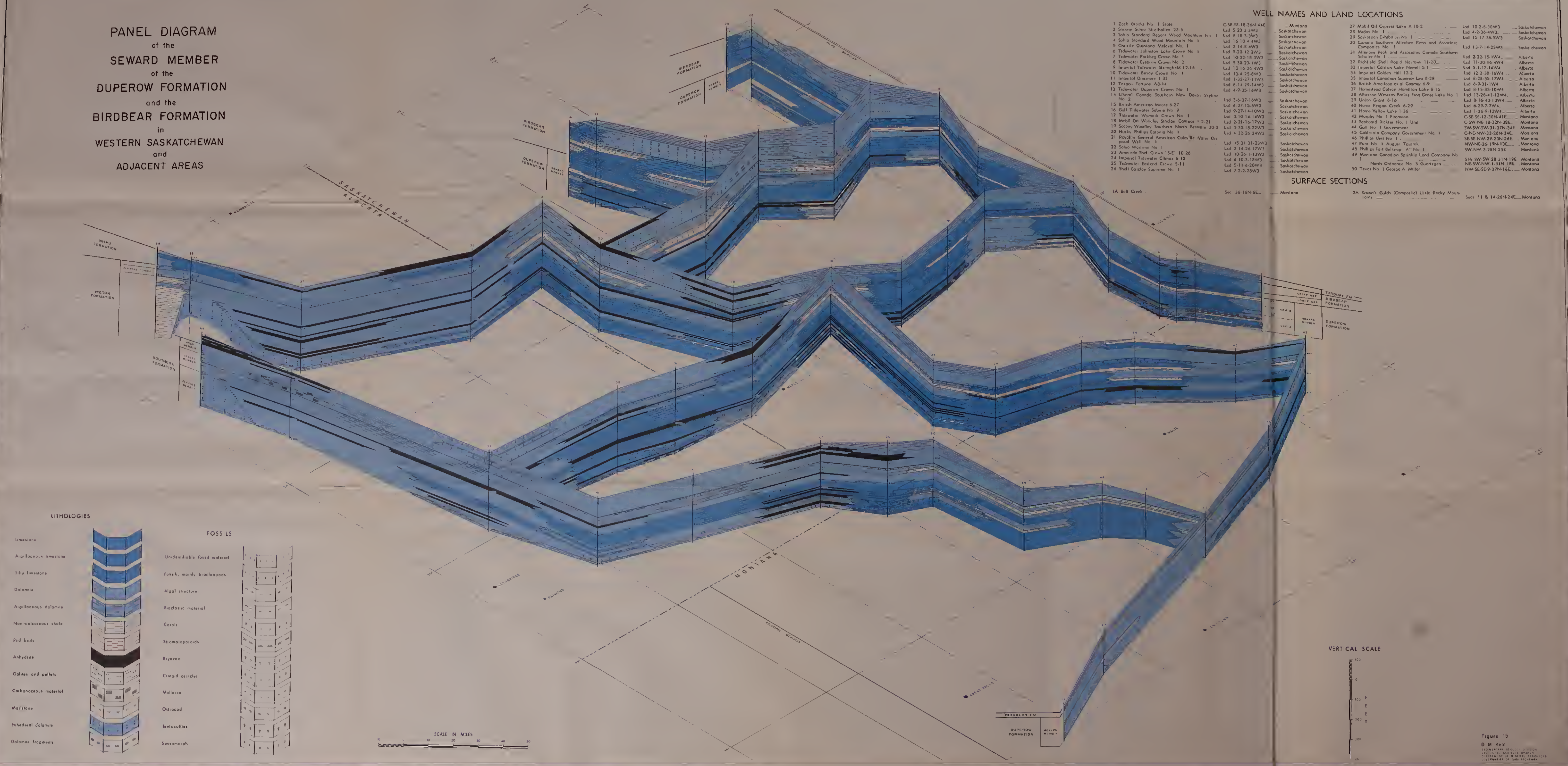
ISOPACH MAP
of the
SEWARD MEMBER of the DUPEROW FORMATION
in
WESTERN SASKATCHEWAN and ADJACENT AREAS

Figure 14

D M Kent



PANEL DIAGRAM
of the
SEWARD MEMBER
of the
DUPEROW FORMATION
and the
BIRDBEAR FORMATION
in
WESTERN SASKATCHEWAN
and
ADJACENT AREAS



WELL NAMES AND LAND LOCATIONS

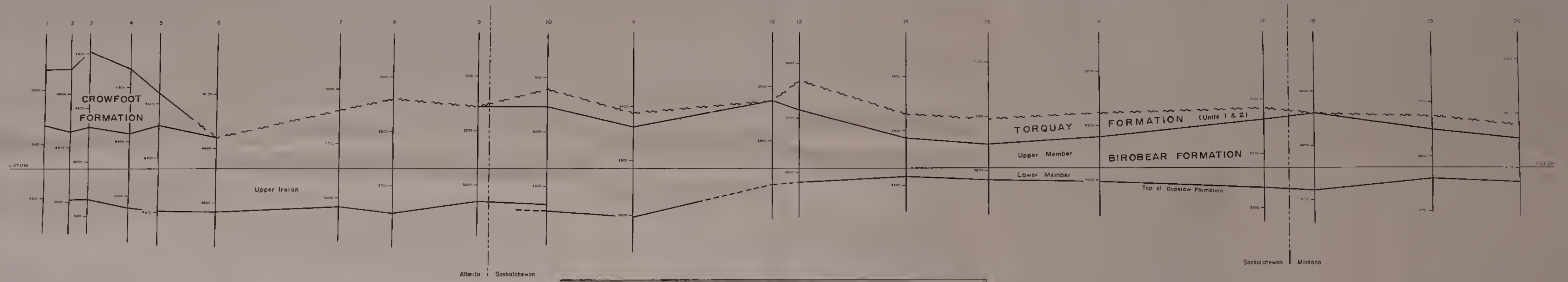
1	Zach Brooks No 1 State	C-SE-SE-18-36N 44E	Montana
2	Socony Sohio Strathallen 23-5	Lsd 5-23 2-3W3	Saskatchewan
3	Sohio Standard Regent Wood Mountain No 1	Lsd 9-18 3-3W3	Saskatchewan
4	Sohio Standard Wood Mountain No 1	Lsd 16 10 4 4W3	Saskatchewan
5	Christie Quintana Meloval No. 1	Lsd 2-14-8 4W3	Saskatchewan
6	Tidewater Johnston Lake Crown No 1	Lsd 9-20-12 2W3	Saskatchewan
7	Tidewater Parkbeg Crown No 1	Lsd 10-32-18-3W3	Saskatchewan
8	Tidewater Eyebrow Crown No 2	Lsd 5-30-23-1W3	Saskatchewan
9	Imperial Tidewater Strongfield 12-16	Lsd 12-16-26-4W3	Saskatchewan
10	Tidewater Birsay Crown No 1	Lsd 13-4 25-8W3	Saskatchewan
11	Imperial Dinsmore 1-32	Lsd 1-32-27-11W3	Saskatchewan
12	Texaco Fortune A8-14	Lsd 8-14 29-14W3	Saskatchewan
13	Tidewater Duperow Crown No 1	Lsd 4-9-35-16W3	Saskatchewan
14	Liberal Canada Southern New Devon Skyline No 2	Lsd 3-6-37-16W3	Saskatchewan
15	British American Moore 6-27	Lsd 6-27-15-6W3	Saskatchewan
16	Gulf Tidewater Sabine No 9	Lsd 9-27-14-10W3	Saskatchewan
17	Tidewater Wymark Crown No 1	Lsd 3-10-14-14W3	Saskatchewan
18	Mobil Oil Woodley Sinclair Cantuar X 2-21	Lsd 2-21-16-17W3	Saskatchewan
19	Socony-Woodley Southern North Bestville 30-3	Lsd 3-30-18-22W3	Saskatchewan
20	Husky Phillips Eatonia No 1	Lsd 4 32-26 24W3	Saskatchewan
21	Royalite General American Coleville Water Disposal Well No 1	Lsd 15 31 31-23W3	Saskatchewan
22	Sohio Wartime No 1	Lsd 2-14-26-17W3	Saskatchewan
23	Amerada Shell Crown "S-E" 10-26	Lsd 10-26-1-13W3	Saskatchewan
24	Imperial Tidewater Climax 6-10	Lsd 6 10-3-18W3	Saskatchewan
25	Tidewater Eastend Crown 5-11	Lsd 5-11-6-20W3	Saskatchewan
26	Shell Barclay Supreme No 1	Lsd 7-2-2-28W3	Saskatchewan
27	Mobil Oil Cypress Lake X 10-2	Lsd 10-2-5-30W3	Saskatchewan
28	Midas No 1	Lsd 4-2-36-4W3	Saskatchewan
29	Saskatoon Exhibition No 1	Lsd 15-17-36-5W3	Saskatchewan
30	Canada Southern Allenbee Keno and Associate Companies No 1	Lsd 13-7-14-25W3	Saskatchewan
31	Allenbee Peak and Associates Canada Southern Schuler No 1	Lsd 2-22-15-1W4	Alberta
32	Richfield Shell Rapid Narrows 11-20	Lsd 11-20-16-4W4	Alberta
33	Imperial Carlson Lake Newell 5-1	Lsd 5-1-17-14W4	Alberta
34	Imperial Golden Hill 12-2	Lsd 12-2-30-16W4	Alberta
35	Imperial Canadian Superior Leo 8-28	Lsd 8-28-35-17W4	Alberta
36	British American et al Conmer 6-9	Lsd 6-9-31-1W4	Alberta
37	Homestead Calvan Hamilton Lake 8-15	Lsd 8-15-35-10W4	Alberta
38	Albercan Western Prairie Fina Goose Lake No 1	Lsd 13-28-41-12W4	Alberta
39	Union Grant 8-16	Lsd 8-16-43-13W4	Alberta
40	Home Peigan Creek 6-29	Lsd 6-29-7-7W4	Alberta
41	Home Yellow Lake 1-36	Lsd 1-36-9-13W4	Alberta
42	Murphy No 1 Firemoon	C-SE-SE-12-30N-41E	Montana
43	Seaboard Richter No. 1 Unit	C-SW-NE-18-32N-38E	Montana
44	Gulf No 1 Government	SW-SW-SW-31-37N-34E	Montana
45	California Company Government No. 1	C-NE-NW-33-26N-34E	Montana
46	Phillips Unit No 1	SE-SE-NW-29-23N-26E	Montana
47	Pure No 1 August Tesorek	NW-NE-26-19N-13E	Montana
48	Phillips Fort Belknap "A" No 1	SW-NW-3-28N 23E	Montana
49	Montana Canadian Sprinkle Land Company No 1	S½-SW-SW-28-31N-19E	Montana
	North Ordnance No 5 Guertzgen	NE-SW-NW-1-31N-19E	Montana
50	Texas No 1 George A Miller	NW-SE-SE-9-37N-18E	Montana

SURFACE SECTIONS

1A	Belt Creek	Sec 36-16N-6E	Montana
2A	Brown's Gulch (Composite) Little Rocky Mountains	Secs 11 & 14-26N-24E	Montana

Figure 15

D M Kent

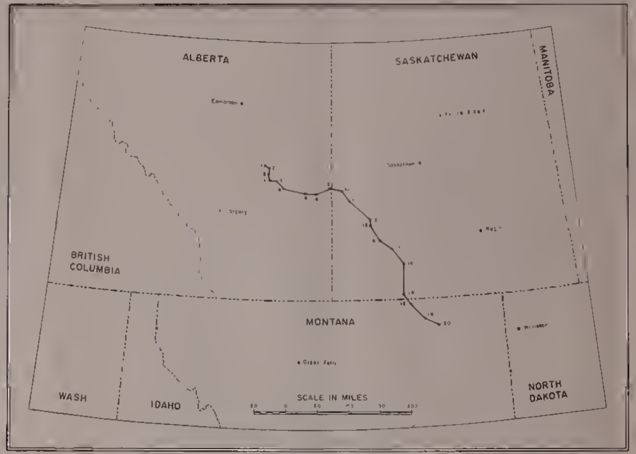


WELL NAMES AND LAND LOCATIONS

1 British American Cities Service Hackett No 1	Lsd 13-15-36-18W4	Alberta
2 Imperial Canadian Superior Leo 8-28	Lsd 8-28-35-17W4	Alberta
3 Western Byemoore 34-8	Lsd 8-34-34 17W4	Alberta
4 Socony Craigmyle No 1	Lsd 12-32-32-16W4	Alberta
5 Hanna Syndicate No 4	Lsd 14-22-32-15W4	Alberta
6 Old Smoky Lawrence No 1	Lsd 10-21-30-13W4	Alberta
7 Western Chinook 11-8	Lsd 11-8-29-7W4	Alberta
8 Hudson Bay Sparky No 1	Lsd 4-12-29-5W4	Alberta
9 British American et al Canmer 6-9	Lsd 6-9-31-1W4	Alberta
10 Husky Phillips Cathy No 1	Lsd 11-17-30-26W3	Saskatchewan
11 Husky Phillips Eatonia No 1	Lsd 4-32-26-24W3	Saskatchewan
12 Tidewater Abbey Crown No. 1	Lsd 3-18-22-19W3	Saskatchewan
13 Imperial Miry Creek 3-6	Lsd 3-6-21-19W3	Saskatchewan
14 Mobil Oil Woodley Sinclair Contual X-2-21	Lsd 2-21-16-17W3	Saskatchewan
15 Tidewater Wymark Crown No 1	Lsd 3-10-14-14W3	Saskatchewan
16 Shell Wood Mountain No 1	Lsd 7-34-9-11W3	Saskatchewan
17 Shell Wood Mountain No. 2	Lsd 13-36-1-12W3	Saskatchewan
18 Gulf No 1 Government	SW-SW-SW-31-37N-34E	Montana
19 Seaboard Rickter No 1 Unit	C-SW-NE-18-32N-38E	Montana
20 Murphy No 1 Firemoon	C-SE-SE-12-30N-41E	Montana

VERTICAL SCALE

FEET



SCHEMATIC CORRELATION SECTION

of the

BIRDBEAR FORMATION and LATERAL EQUIVALENTS

in

WESTERN SASKATCHEWAN and ADJACENT AREAS

SCALE IN MILES

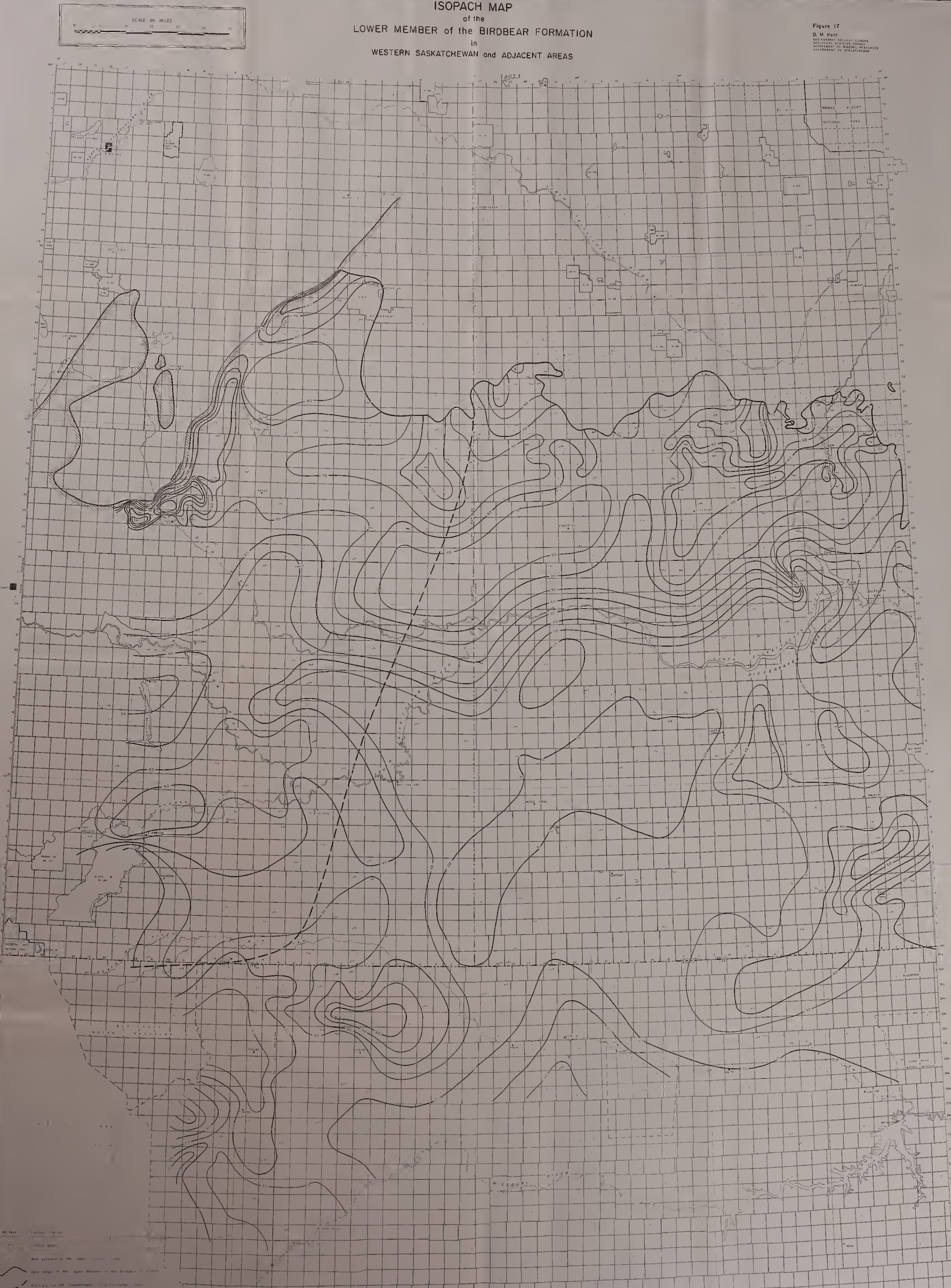
Figure 16

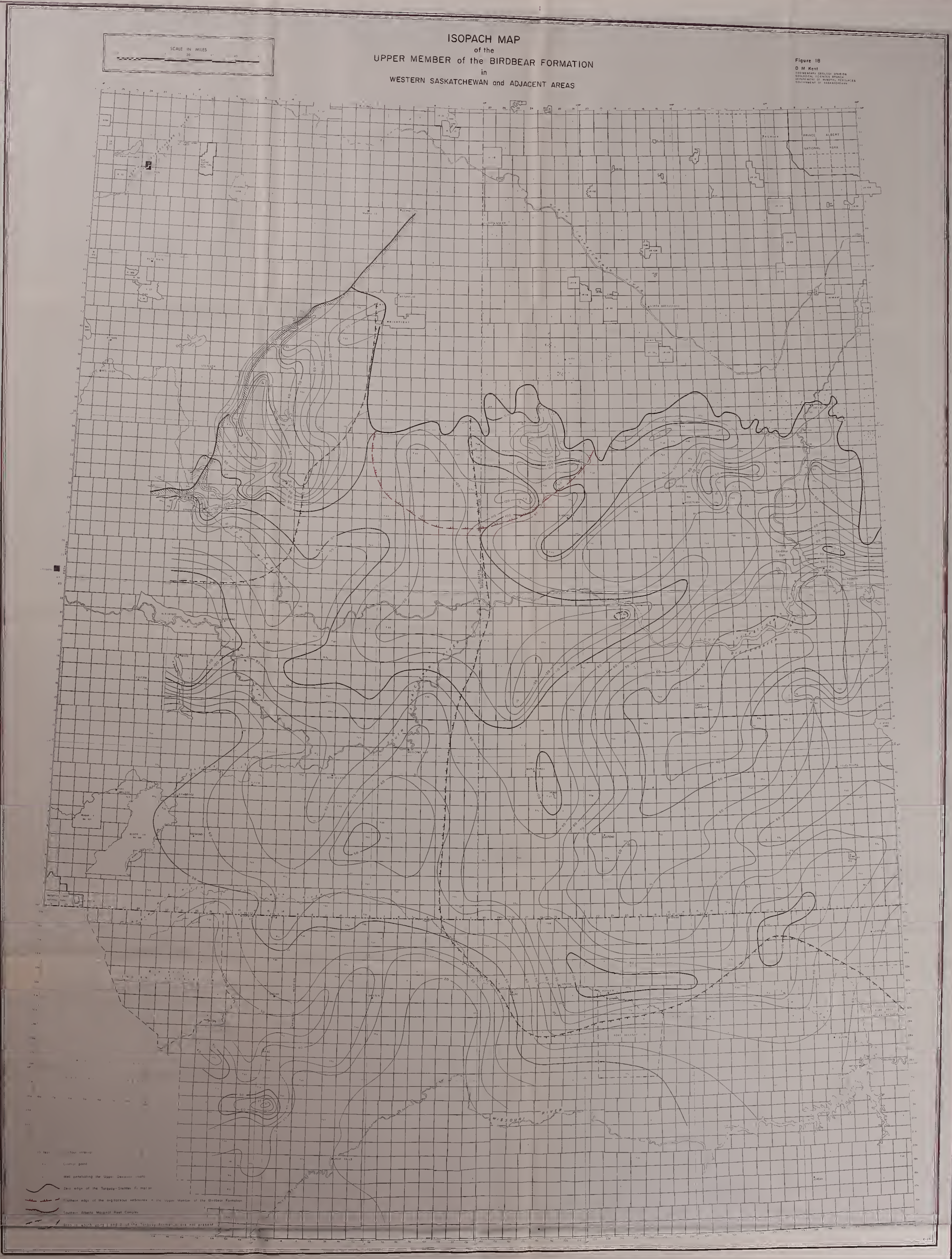
D M Kent
SEDIMENTARY GEOLOGY DIVISION
GEOLOGICAL SCIENCES BRANCH
DEPARTMENT OF MINERAL RESOURCES
GOVERNMENT OF SASKATCHEWAN

ISOPACH MAP
of the
LOWER MEMBER of the BIRDBEAR FORMATION
in
WESTERN SASKATCHEWAN and ADJACENT AREAS

Figure 17

D. M. Kent
SEDIMENTARY GEOLOGY DIVISION
GEOLOGICAL SCIENCES BRANCH
DEPARTMENT OF MINERAL RESOURCES
GOVERNMENT OF SASKATCHEWAN



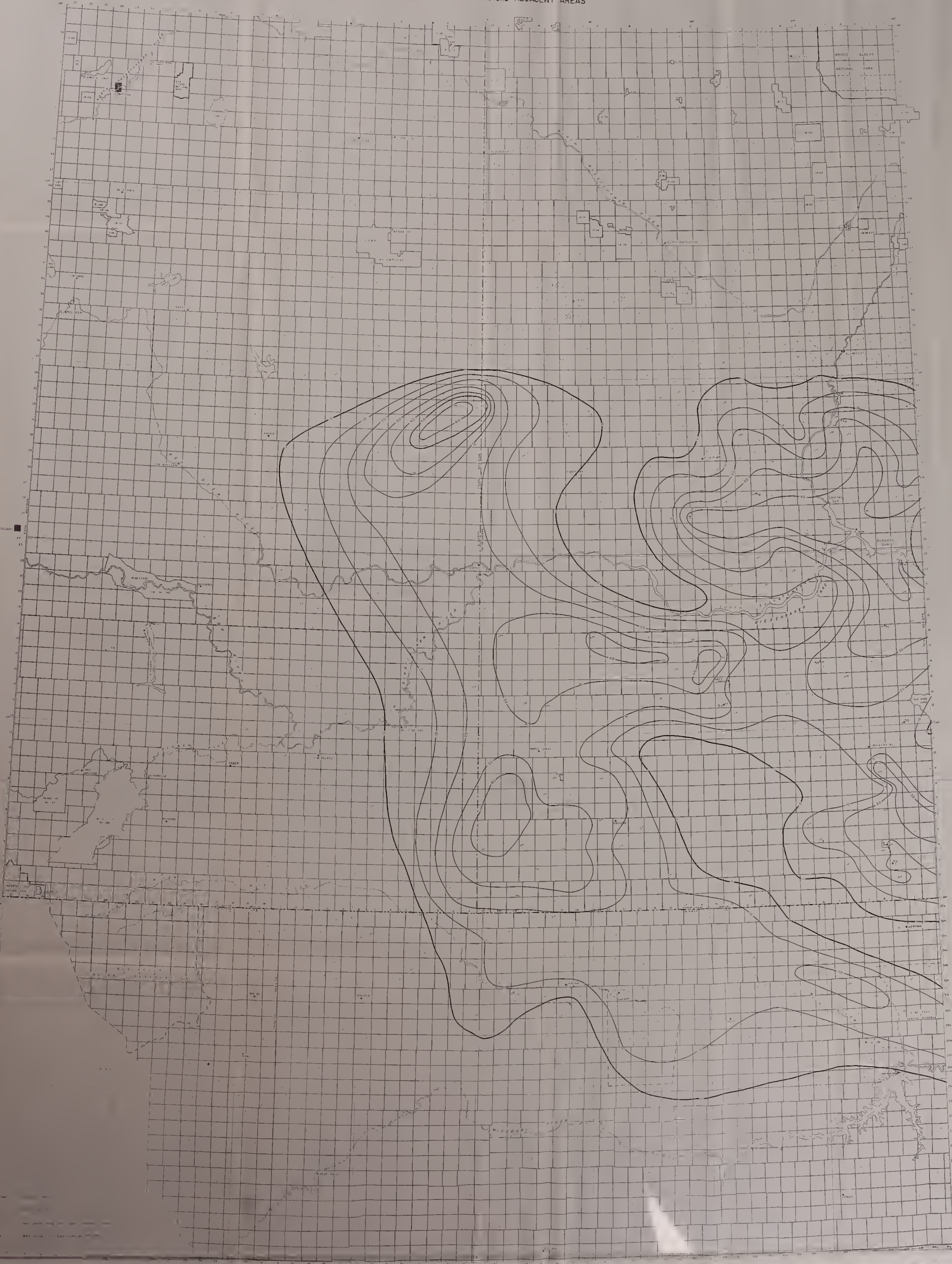


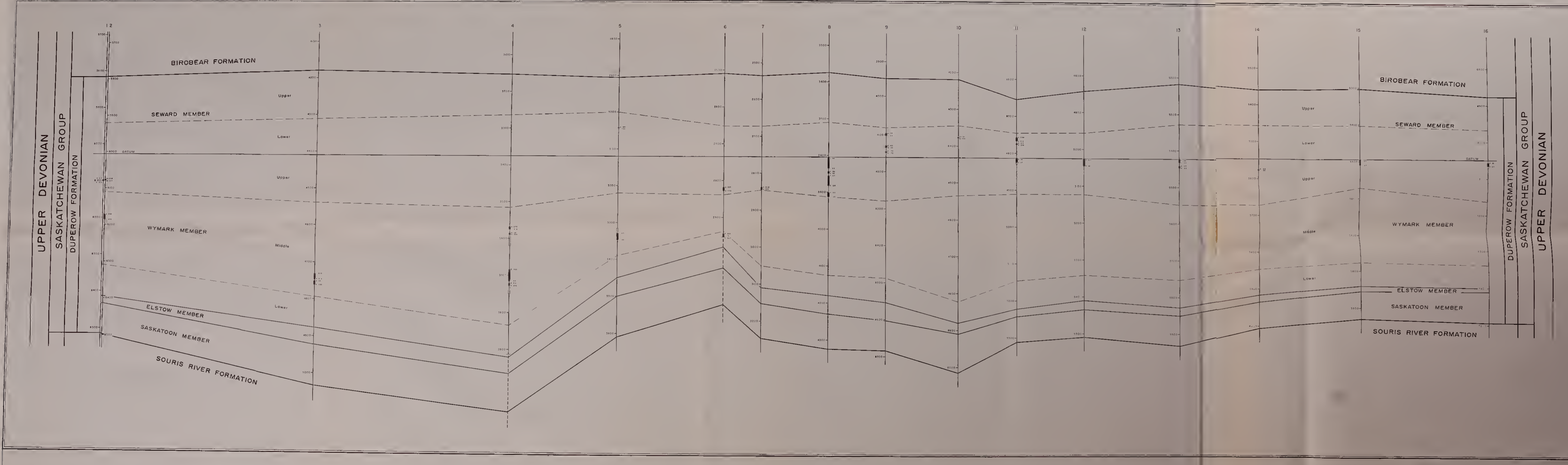
SCALE IN MILES
ISOPACH MAP
of the
UPPER MEMBER of the BIRDBEAR FORMATION
in
WESTERN SASKATCHEWAN and ADJACENT AREAS
Figure 18
D M Kent
PRINCE ALBERT
NATIONAL PARK
MISSOURI RIVER
10 feet Contour interval
Control point
Well penetrating the Upper Devonian strata
Zero edge of the Torquay-Stettler Formation
Southern edge of the argillaceous sediments in the Upper Member of the Birdbear Formation
Southern Alberta Marginal Reef Complex
Area in which units 1 and 2 of the Torquay Formation are not present

ISOPACH MAP
of the
DINSMORE EVAPORITE of the DUPEROW FORMATION
in
WESTERN SASKATCHEWAN and ADJACENT AREAS

Figure 19

D. M. Kent




UPPER DEVONIAN
SASKATCHEWAN GROUP
DUPEROW FORMATION
1 2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
BIROBEAR FORMATION
SEWARD MEMBER
WYMARK MEMBER
ELSTOW MEMBER
SASKATOON MEMBER
SOURIS RIVER FORMATION
Upper
Lower
Middle
DATUM

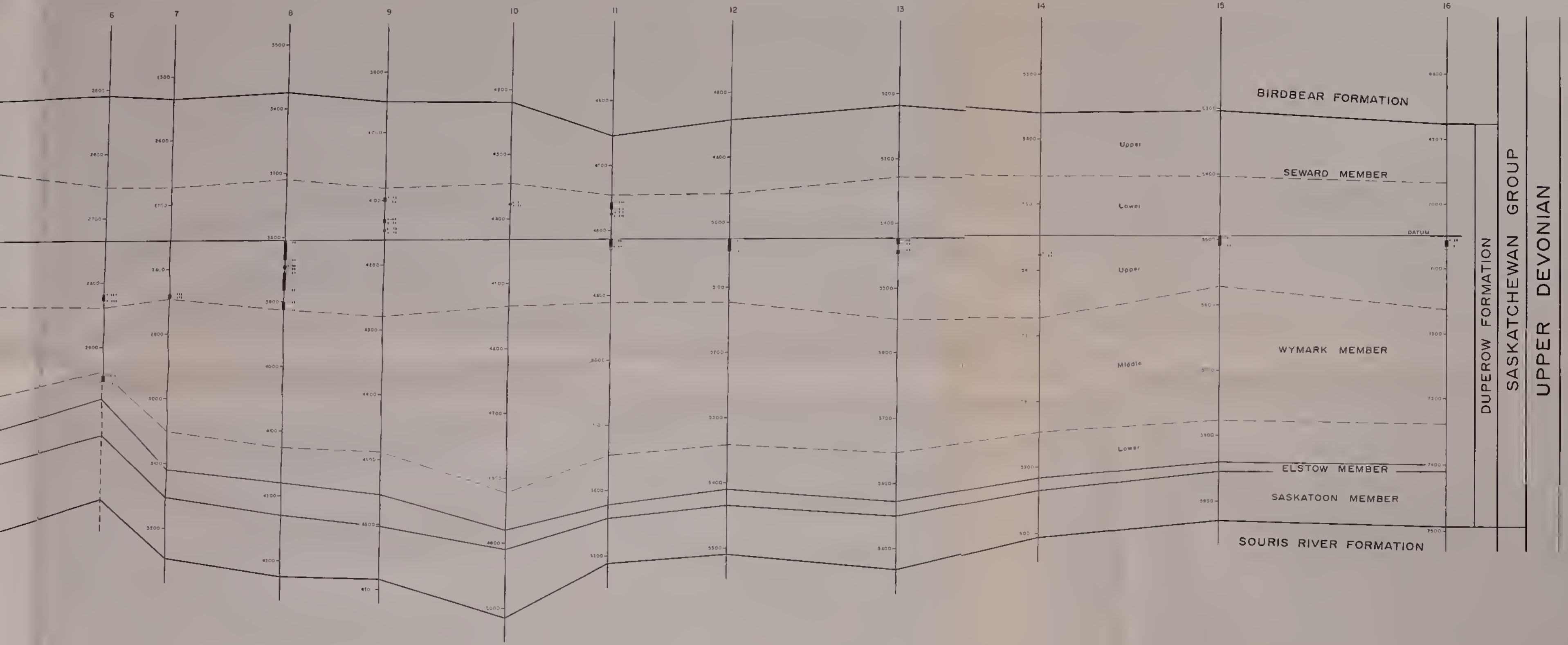
THRO

WELL

Figure 20

D. M. Kent
SEDIMENTARY GEOLOGY DIVISION
GEOLOGICAL SCIENCES BRANCH
DEPARTMENT OF MINERAL RESOURCES
GOVERNMENT OF SASKATCHEWAN

SCHEMATIC CROSS SECTION
THROUGH WELLS EMPLOYED in the GEOCHEMICAL STUDY of the ANHYDRITES of the DUPEROW FORMATION in WESTERN SASKATCHEWAN



VERTICAL SCALE in FEET

HORIZONTAL SCALE in MILES

LEGEND

Cored anhydrite

Partially cored anhydrite

Sample interval

Well not deep enough—lower stratigraphic units projected from nearby well

Formation boundary

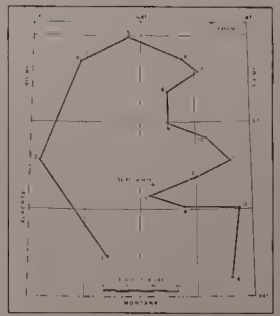
Member boundary

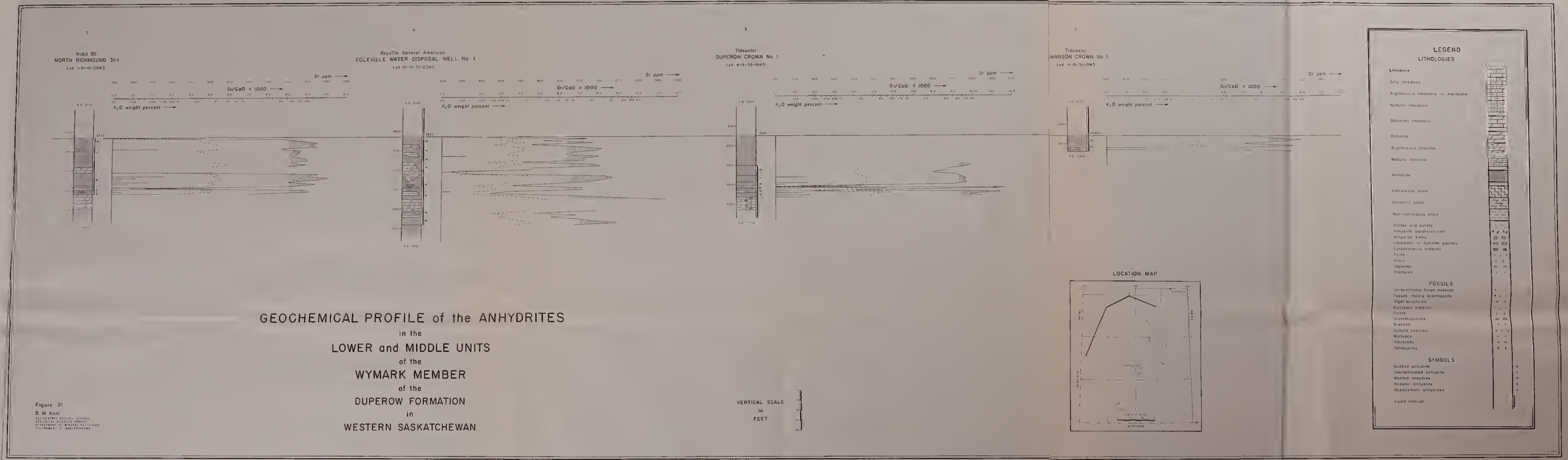
Informal unit boundary

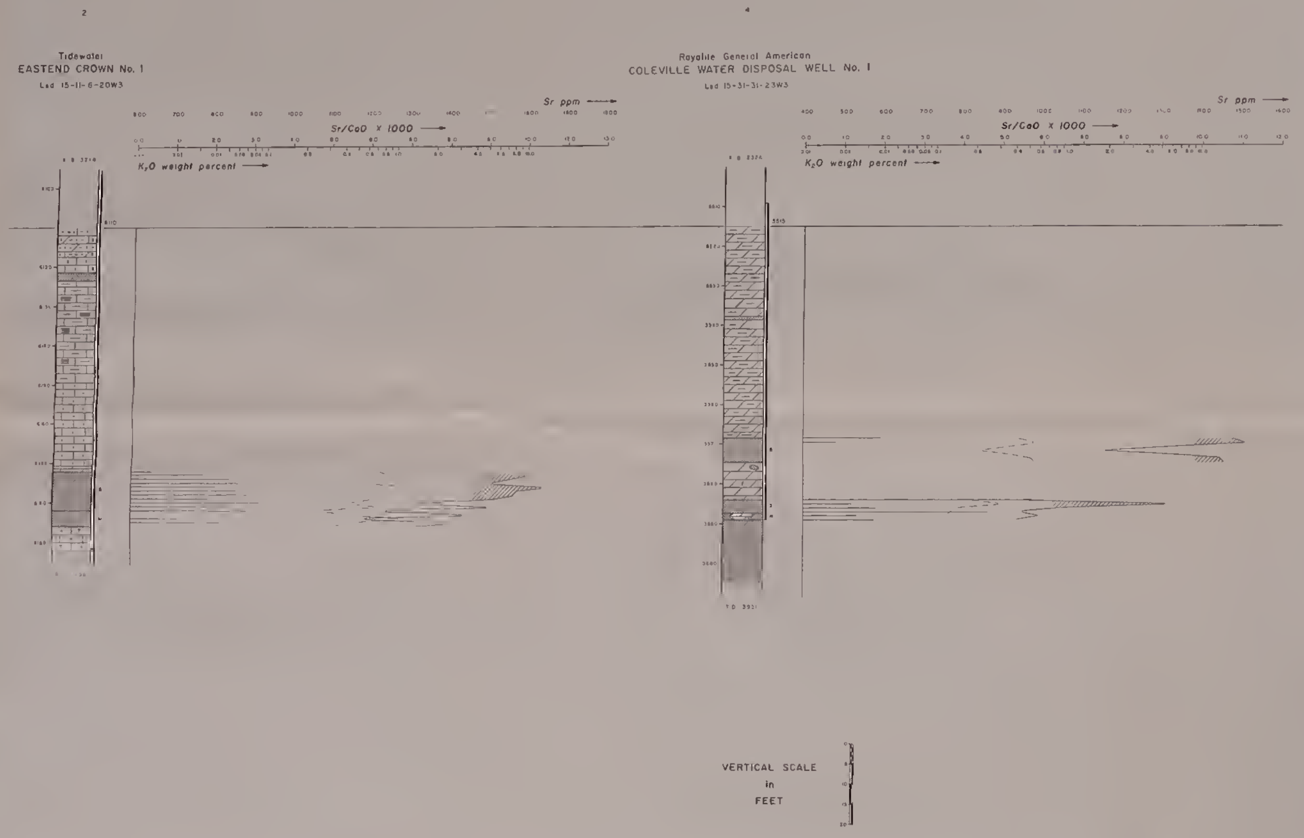
WELL NAMES AND LAND LOCATIONS

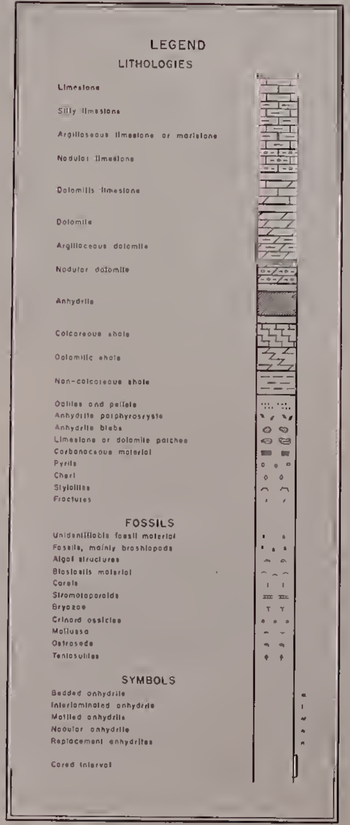
1 Tidewater Eastend Crown 5-12	Lsd 5-12-6-20W3
2 Tidewater Eastend Crown No. 1	Lsd 15-11-6-20W3
3 Mobil Oil North Richmound 31-1	Lsd 1-31-18-28W3
4 Royalite General American Coleville Water Disposal Well No 1	Lsd 15-31-31-23W3
below 3911' Coleville Unit 5-30	Lsd 15-30-31-23W3
5 Tidewater Duperow Crown No 1	Lsd 4-9-35-16W3
6 Tidewater Swanson Crown No 1	Lsd 4-8-32-9W3
below 2954' Tidewater Swanson Crown No 2	Lsd 16-9-32-8W3
7 Tidewater Imperial Outlook Crown No 1	Lsd 7-20-30-7W3
8 Imperial Dinsmore 1-32	Lsd 1-32-27-11W3
9 Tidewater Beechy Crown No 1	Lsd 11-29-23-11W3
10 Imperial Lawson No 1	Lsd 16-31-21-6W3
11 Tidewater Parkbeg Crown No. 1	Lsd 10-32-18-3W3
12 Tidewater Morse Crown No 1	Lsd 16-25-16-8W3
13 Tidewater Wymark Crown No. 1	Lsd 3-10-14-14W3
14 Tidewater Vanguard Crown No 1	Lsd 14-30-12-9W3
15 Tidewater Johnston Lake Crown No. 1	Lsd 9-20-12-2W3
16 Sohio Standard Regent Wood Mountain No. 1	Lsd 9-18-3-3W3

LOCATION MAP




3
Mobil Oil
NORTH RICHMOUND 31-1
Lsd 1-31-18-28W3
4
Royalite General American
COLEVILLE WATER DISPOSAL WELL No 1
Lsd 15-31-31-23W3
5
Tidewater
DUPEROW CROWN No 1
Lsd 4-9-35-16W3
6
Tidewater
WANSON CROWN No 1
Lsd 4-8-32-9W3
Sr ppm
Sr/CaO x 1000
K2O weight percent
LOCATION MAP
GEOCHEMICAL PROFILE of the ANHYDRITES
in the
LOWER and MIDDLE UNITS
of the
WYMARK MEMBER
of the
DUPEROW FORMATION
in
WESTERN SASKATCHEWAN
Figure 21
D. M Kent
VERTICAL SCALE
in
FEET
LEGEND
LITHOLOGIES
Limestone
Silty limestone
Argillaceous limestone or marlstone
Nodular limestone
Dolomitic limestone
Dolomite
Argillaceous dolomite
Nodular dolomite
Anhydrite
Calcareous shale
Dolomitic shale
Non-calcareous shale
Oolites and pellets
Anhydrite porphyrocrysts
Anhydrite blebs
Limestone or dolomite patches
Carbonaceous material
Pyrite
Chert
Stylolites
Fractures
FOSSILS
Unidentifiable fossil material
Fossils mainly brachiopods
Algal structures
Bioclastic material
Corals
Stromatoporoids
Bryozoa
Crinoid ossicles
Mollusca
Ostracods
Tentaculites
SYMBOLS
Bedded anhydrite
Interlaminated anhydrite
Mottled anhydrite
Nodular anhydrite
Replacement anhydrites
Cored interval





GEOCHEMICAL PROFILE of the ANHYDRITE

in the

MIDDLE UNIT

of the

WYMARK MEMBER

of the

DUPEROW FORMATION

in

WESTERN SASKATCHEWAN

LOCATION MAP

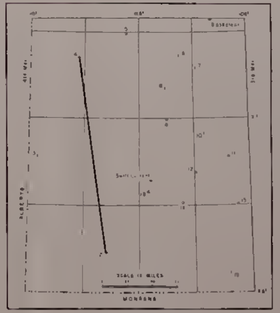


Figure 22

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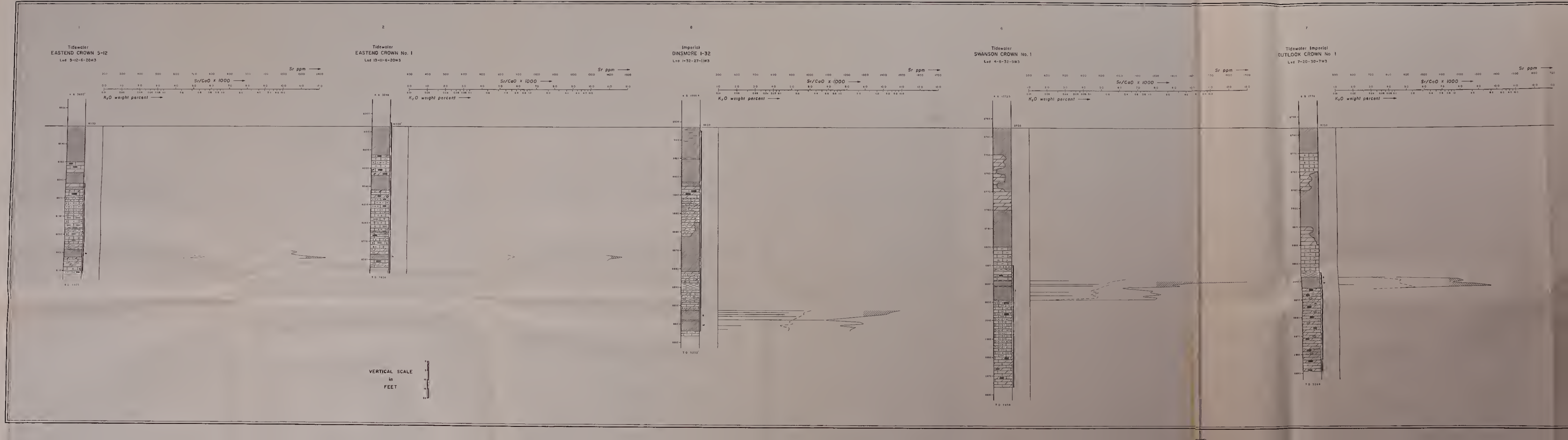
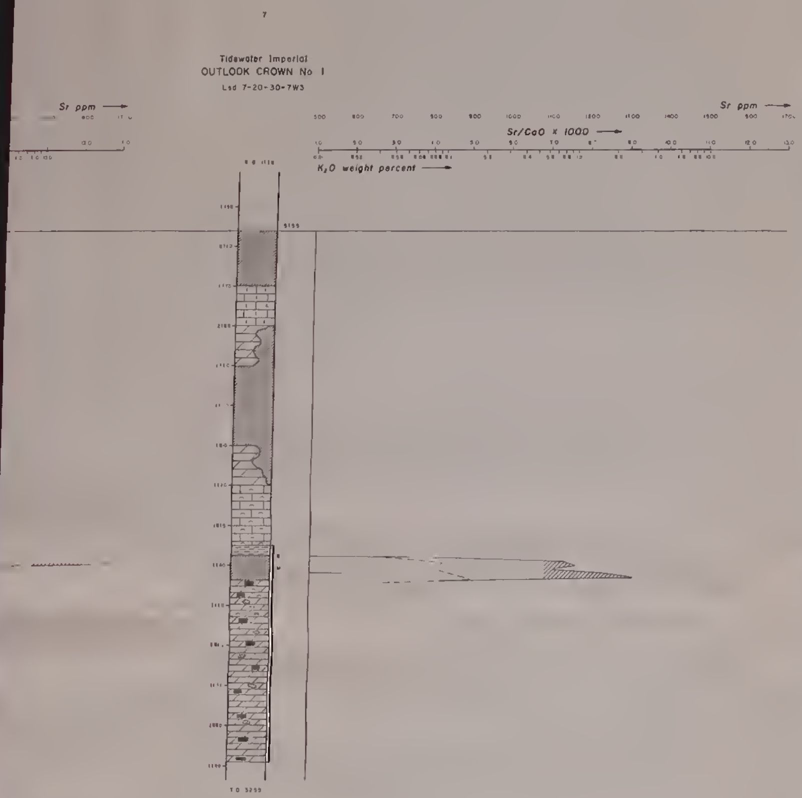
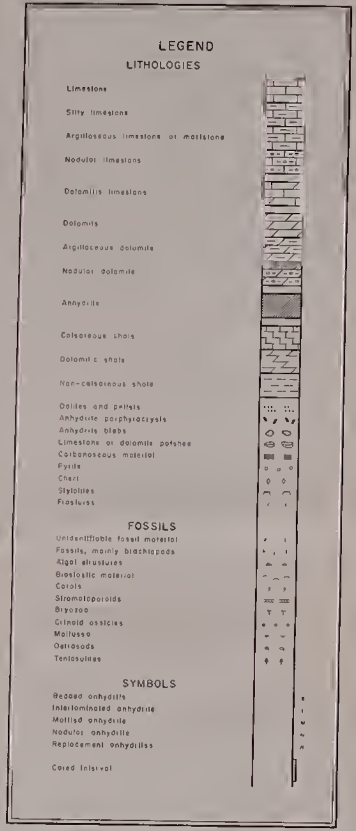
DEPARTMENT OF MINERAL RESOURCES
GOVERNMENT OF SASKATCHEWAN

A-285



1
Tidewater
EASTEND CROWN 5-12
Lsd 5-12-6-20W3
Sr ppm
Sr/CaO x 1000
K_2O weight percent
2
Tidewater
EASTEND CROWN No. 1
Lsd 15-11-6-20W3
Sr ppm
Sr/CaO x 1000
K_2O weight percent
8
Imperial
DINSMORE 1-32
Lsd 1-32-27-11W3
Sr ppm
Sr/CaO x 1000
K_2O weight percent
6
Tidewater
SWANSON CROWN No. 1
Lsd 4-8-32-9W3
Sr ppm
Sr/CaO x 1000
K_2O weight percent
7
Tidewater Imperial
OUTLOOK CROWN No 1
Lsd 7-20-30-7W3
Sr ppm
Sr/CaO x 1000
K_2O weight percent
VERTICAL SCALE
in
FEET





GEOCHEMICAL PROFILE of the ANHYDRITE

near the base of the

UPPER UNIT

of the

WYMARK MEMBER

of the

DUPEROW FORMATION

in

WESTERN SASKATCHEWAN

LOCATION MAP

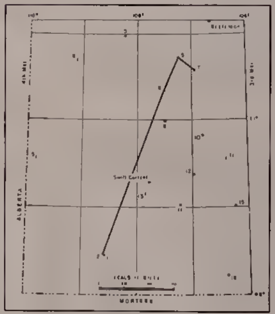


Figure 23

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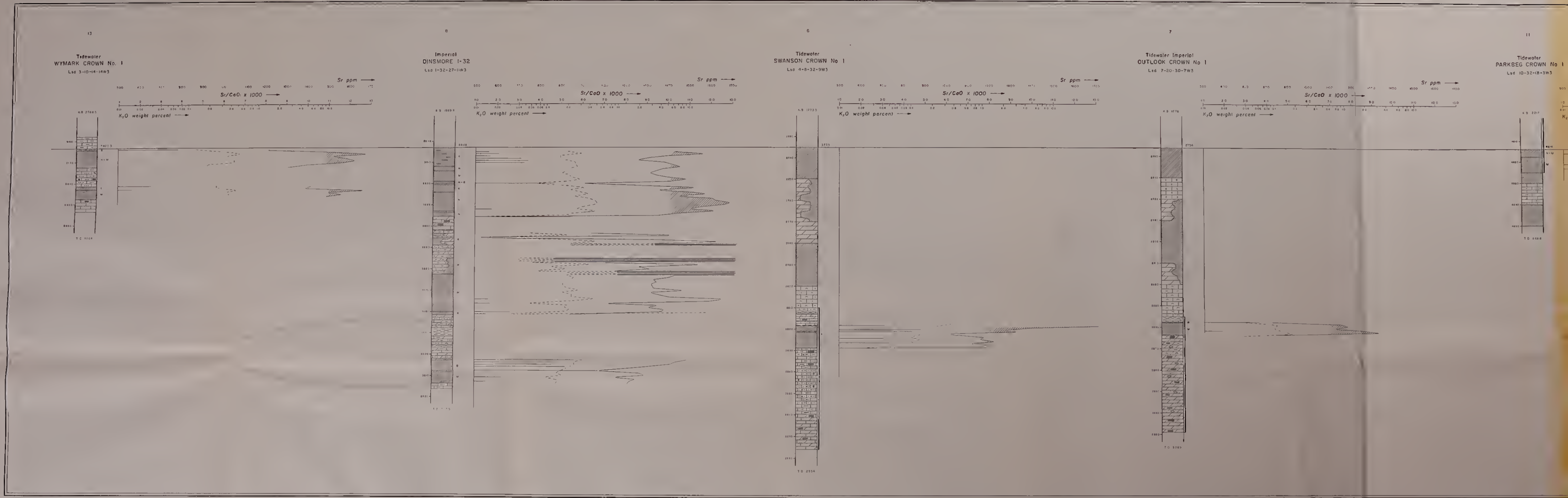
GOVERNMENT OF SASKATCHEWAN


13
Tidewater
WYMARK CROWN No. 1
Lsd 3-10-14-14W3
8
Imperial
DINSMORE 1-32
Lsd 1-32-27-11W3
6
Tidewater
SWANSON CROWN No 1
Lsd 4-8-32-9W3
7
Tidewater Imperial
OUTLOOK CROWN No 1
Lsd 7-20-30-7W3
11
Tidewater
PARKBEG CROWN No 1
Lsd 10-32-18-3W3
Sr ppm
Sr/CaO x 1000
K2O weight percent

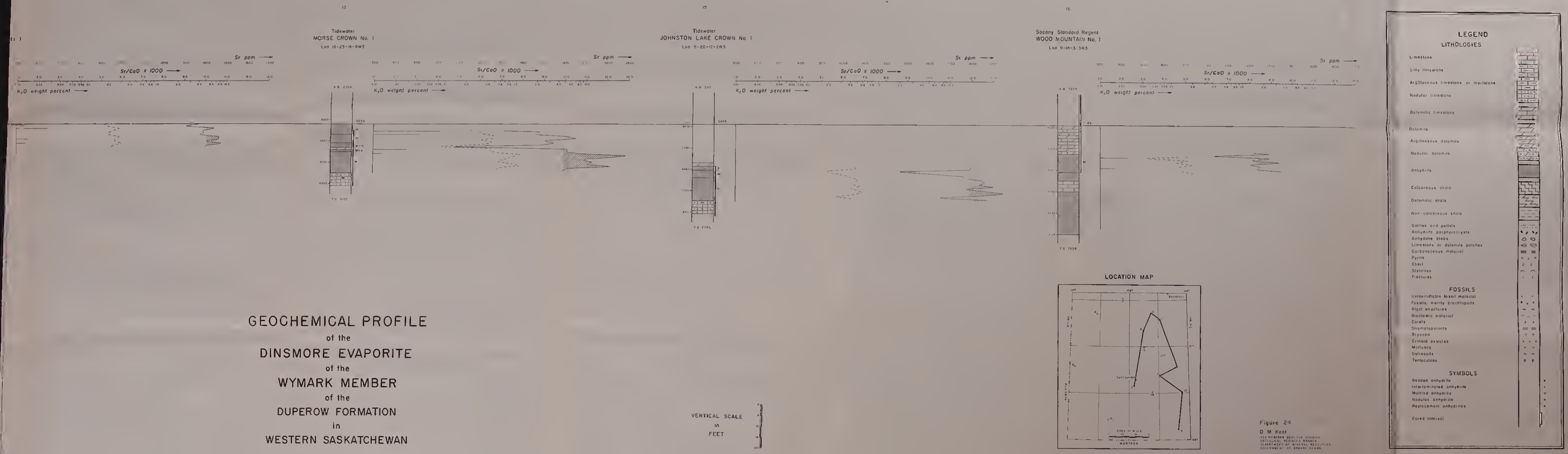
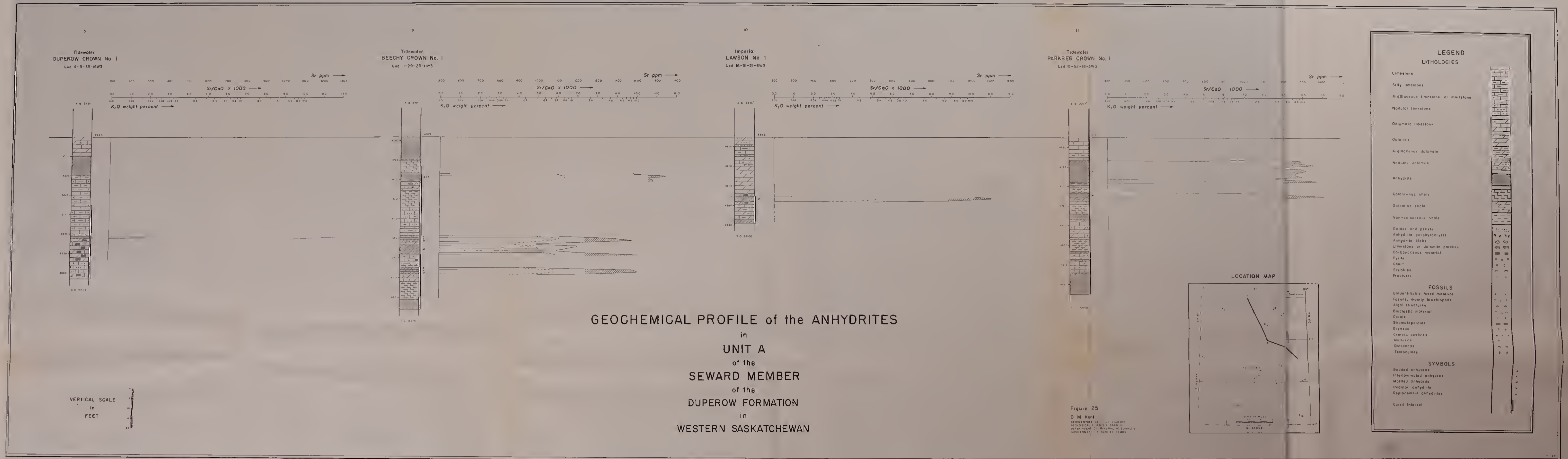


Figure 24

D M Kent


5
Tidewater
DUPEROW CROWN No. 1
Lsd 4-9-35-16W3
9
Tidewater
BEECHY CROWN No. 1
Lsd 1-29-23-11W3
10
Imperial
LAWSON No. 1
Lsd 16-31-21-6W3
11
Tidewater
PARKBEG CROWN No. 1
Lsd 10-32-18-3W3
Sr ppm →
Sr/CaO x 1000 →
K_2O weight percent →
GEOCHEMICAL PROFILE of the ANHYDRITES
in
UNIT A
of the
SEWARD MEMBER
of the
DUPEROW FORMATION
in
WESTERN SASKATCHEWAN
VERTICAL SCALE
in
FEET
LOCATION MAP
LEGEND
LITHOLOGIES
Limestone
Silty limestone
Argillaceous limestone or marlstone
Nodular limestone
Dolomitic limestone
Dolomite
Argillaceous dolomite
Nodular dolomite
Anhydrite
Calcareous shale
Dolomitic shale
Non-calcareous shale
Oolites and pellets
Anhydrite porphyrocrysts
Anhydrite blebs
Limestone or dolomite patches
Carbonaceous material
Pyrite
Chert
Stylolites
Fractures
FOSSILS
Unidentifiable fossil material
Fossils, mainly brachiopods
Algal structures
Bioclastic material
Corals
Stromatoporoids
Bryozoa
Crinoid ossicles
Mollusca
Ostracods
Tentaculites
SYMBOLS
Bedded anhydrite
Interlaminated anhydrite
Mottled anhydrite
Nodular anhydrite
Replacement anhydrites
Cored interval
Figure 25
D. M. Kent

ISOPACH MAP
of the
INTERVAL between the TOP of the LOWER MEMBER of the BIRDBEAR FORMATION
and the TOP of the SOURIS RIVER FORMATION
in
WESTERN SASKATCHEWAN and ADJACENT AREAS

Figure 28

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GEOLOGICAL SCIENCES BRANCH
DEPARTMENT OF MINERAL RESOURCES
GOVERNMENT OF SASKATCHEWAN